ISOKINETIC REHABILITATION OF ANKLE SPRAIN

By

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CONTENT

ABSTRACT

In most people's minds, ankle sprain often appears to be trivial because it is quite a common sports injury. However, related residual symptoms are often reported by athletes with sprains.

An epidemiological survey on ankle sprain was conducted among local Hong Kong Chinese athletes between June 1990 to June 1991 with a total of 380 respondents. This survey revealed that 73.5% of athletes had sustained recurrent ankle sprains, and 59.0% of ankle sprains had related residual symptoms. Athletes often felt these residual symptoms hinder their level of athletic performance. The higher the recurrent rate of sprain, the more the athletes felt that their level of performance was affected. 77.4% of athletes with 5 or more sprains reported that their sports performance was being affected physically, psychologically or both. Apart from pain, instability and weaknesses of ankles were the major residual symptoms.

Pain and immobility resulted from ankle sprain would lead to secondary muscle atrophy, thus muscle weakness

was often reported. This muscle weakness, especially the ankle evertor, caused a decrease in dynamic support of the ankle mortise and put the ankle joint into the risk of recurrent injuries. However, there is a lack of comprehensive and objective assessment in evaluating muscular status of the ankle following sprain, and also a lack of a well-planned muscle rehabilitation programme in improving ankle strength and ankle function.

Isokinetic testing for ankle dorsiflexion, plantar-flexion, inversion and eversion at slow (60°/sec) and fast (180°/sec) speeds were employed in this study to obtain a complete profile of various muscular parameters of the ankle including peak torque, average power, total work and torque acceleration energy. A baseline study for subjects with bilateral non-injured ankles was first carried out to obtain normative data for comparison between dominant and non-dominant ankles. Isokinetic evaluation, and a subjective ankle evaluation with an ankle functional rating scale assessment form, were then carried out among subjects with unilateral recurrent ankle sprains. Isokinetic testing results revealed a generalized decrease in various muscular parameters in the injured dominant ankle; and a significant decrease in various muscular parameters of ankle evertor in the injured ankles (P<0.05).

An isokinetic velocity spectrum training protocol was designed for exercising the injured ankles. This protocol included a spectrum of velocities for training different types of muscle fibers for enhancing neurological and motor responses. Results in the retest indicated that this exercise protocol was effective in improving all muscular parameters of the ankle (P<0.05). It also enhanced the functional performance of the injured ankles through the subjective ankle functional rating scale re-evaluation (P<0.05).

Results of this study showed that ankle sprain was never a trivial injury. Muscle weakness especially the ankle evertor was present through an objective isokinetic assessment of various muscular parameters of the ankle. Strengthening of the weakened ankle showed that a positive effect in enhancing the functional performance of the ankle could also be attained.

I.INTRODUCTION

One of the most common traumatic injuries in the sports population is ankle sprain. Cetti (1982) reported that 61% of ankle sprain occurred during sports activities. Smith (1986) in his study reported that 70% of his basketball players had previous history of ankle sprains and 80% had multiple episodes. Lewin (1989) reported that the ankle joint was the most frequently injured joint in his professional English Soccer Club and the lateral collateral ligaments were the most frequently injured ligaments. Various epidemiology studies on sports injuries also found that ankle sprain occurred very frequently among the sportsman (13,53,115,127,159). Ekstrand et al (1982, 1983), in his studies of soccer injuries over one year period, reported that 17% of all injuries involved the ankles which included one case of ankle fracture. He also reported that ankle injuries comprised 23% of all injuries and was the most common injury in soccer players. An injury study conducted by the Sports Medicine Department, Jubilee Sports Center (now Hong Kong Sports Institute) from January 1988 to April 1989, reported that 74 out of 496 cases of injuries recorded were ankle sprains. It comprised 14.9% of all injuries. This injury rate was similar to other studies.

Many authors had reported on the high recurrent rate of ankle sprain, and athletes' complaint of sense of "giving way" or instability of the sprained ankles even after years of follow-up (35,52,70,109,125,127). An old saying : "once a sprain, always a sprain" seems to hold true. In many cases, the injury was neglected and many athletes did not seek any medical attention (125). In a Chinese society like Hong Kong, often injured ankles were treated by bone-setter for the control of pain and swelling, and a proper post-traumatic rehabilitation programme for functional return after the injury was often neglected.

There are a number of attributing factors for recurrent ankle sprains, or functional instability of the ankle causing it to easily give way. These factors include muscular weaknesses of the ankle, decrease in proprioceptive sense of the ankle joint, tightness of calf muscle and joint laxity (8,67,78,109,111,135,143). Therefore, in the rehabilitation of ankle sprain, muscle strengthening exercises for improving strength of the ankle, exercises aimed at improving muscular coordination and balance, proprioception exercise for improving joint sense and stretching exercise for improving flexibility of the calf muscle were the suggested treatment protocol (26,78,82,111,135,143). Residual ankle problems resulting from sprain could very often be resolved after a programme of muscle strengthening, balance and proprioceptive training, and muscle stretching exercise (15,34). Lindenfeld (1989) reported that majority of patients with ankle sprains were relieved of ankle residual symptoms and recurrent sprains by peroneal strengthening exercise alone.

Although operative reconstructions for lateral ankle ligaments were reported to be successful in improving stability of ankle joints (65,110). Most ankle sprains were still managed conservatively .

Weaknesses of musculature around the ankle, especially ankle evertors and dorsiflexors, were often noted after inversion ankle sprain (3,67,78,128). Evertors and dorsiflexors are important as they act as a dynamic back-up to lateral ligaments of the ankle for prevention of inversion sprain. Weaknesses of these muscles often lead to functional instability of the ankle. Thus in a rehabilitation programme for ankle injury, strengthening the musculature around the ankle is essential in developing muscular balance and increasing stability of the ankle for the prevention of recurrent ankle sprains (8,26,46,67,74,75,78,82,109,125,135).

There are various types of strengthening exercises, namely isometric, isotonic and isokinetic exercises. Isometric is a static form of exercise at which there is no observable joint movement. Isotonic exercise involves movement against a constant resistance, and because of the changes in leverage during joint motion, the muscle is mainly loaded maximally at its weakest point in the range of motion. Isokinetic exercise is a relatively new concept. This type of exercise is performed at a constant speed, that is, velocity of movement is controlled and remained constant. The speed of movement can be selected by clinician. This form of exercise requires specially designed equipment, for example, Cybex isokinetic testing and rehabilitation system, Biodex isokinetic system, Kin-com isokinetic system, etc.

The advantages of isokinetic exercise over other types of exercise are as follows. Firstly, the amount of resistance provided by the machine always matches the amount of force the subject exerts in trying to move the limb faster than the controlled speed. Increase in effort could only result in increasing resistance, so muscles can be maximally loaded throughout the entire range of motion. Secondly, at those points in the range of motion where the muscle is either weakened because of pain, or less efficient because of leverage changes or joint instability, the isokinetic machine would decrease its resistance accordingly. This means isokinetic machine can accommodate muscle weakness due to pain, joint instability or leverage changes and thus present less chances of musculoskeletal injury. Furthermore, our body movements occur at various speeds depending on kinds of activities, the isokinetic machine has the advantage of providing variable speeds or velocities in training movements. However, isokinetic machines are relatively expensive pieces of equipment. It is therefore not very popular for strength training.

Isokinetic devices have been widely used for assessing various muscular parameters in different parts of the body. Data obtained from isokinetic testing could provide information concerning the condition of muscles tested; for example, comparing muscular parameters between an injured limb and a non-injured one, pre- and post-training effects, or muscular fitness within a group of subjects. By specifying the movement velocity, isokinetic measurements are highly objective. These measurements could also be easily repeated or re-assessed by other examiners using the same testing protocol, the same testing set-up and similar model of isokinetic apparatus (138).

Many authors had reported that muscle weaknesses, especially the peronei, were detected in ankles that had sustained inversion sprain (3,67,78,128). However, most of these muscular strength evaluations were performed with manual resistance. There were not many objective assessments on ankle muscular strength and power at various speeds of movements, and their relationship with functional performance of the ankle joint being performed.

In view of the high recurrent rate of ankle sprains being reported, and the lack of comprehensive and objective data for muscular parameters of normal ankles and ankle with sprains, this study on ankle sprain was carried out. The main objectives of this study were: firstly, to identify the prevalence of recurrent ankle sprains and its related residual symptoms among Hong Kong sportsmen. Secondly, to obtain an objective and a comprehensive evaluation on various muscular parameters of the ankle in order to develop normative data for normal subjects, that is, subjects with no history of ankle injury. Thirdly, to obtain an objective and comprehensive evaluation for various muscular parameters of the ankle with chronic recurrent sprain, to identify if there are muscular weaknesses of the injured ankle by comparing data of the injured side with the non-injured side, and with the normative data obtained. All muscular parameters will be evaluated with the use of Cybex II+ isokinetic dynamometer (Cybex Division Inc, NX 11779). Fourthly, if muscular weaknesses are detected in subjects with recurrent ankle sprains, an isokinetic rehabilitation programme would be implemented for the injured ankles. The effectiveness of the isokinetic training in increasing the various muscular parameters of the ankles, resulting in the improvement of the dynamic support of the ankle joint will be reassessed. Lastly, to evaluate subjectively if this isokinetic training programme is effective enhancing the functional abilities of the ankle joint.

From this study, both an objective and comprehensive evaluation for ankle muscular parameters following an ankle sprain will be provided. A method for the evaluation of functional capabilities of the ankle with sprain is suggested. It is hoped that these findings can give a deeper insight into a "trivial" traumatic injury as an ankle inversion sprain, and that this can aid the therapists in the planning of an effective and comprehensive rehabilitation programme for ankle sprain. With good rehabilitation following injury, it is hoped that the sprain related residual problems can be minimized and the recurrent rate in ankle sprain can be reduced.

II.LITERATURE REVIEW

2.1 Functional Anatomy of Ankle and Subtalar Joint

The integrity and stability of the ankle depends on its bony configuration, the ligaments around the ankle and dynamic support by the joint associated musculatures (17,26,74,100).

2.1.1 Bony Configuration

The ankle joint is not a true hinge joint, it is a saddle or sellar joint, or a mortise and tenon joint where the dome shaped body of the talus (tenon) fits into a slightly concave undersurface of the tibia. The tibia rotates on the talus about 1/4 distance forward from the hind end of foot. The center of rotation is not fixed and some side rotation is allowed (81,100). The longer lateral malleous extends distally to the level of the subtalar joint thus prevents lateral movement of the talus (100).

2.1.2 Axis of motion

Dorsiflexion and plantarflexion occurs along the transverse talar axis. It is the movement of the talocrural joint. Inversion and eversion occurs along the oblique axis through the calcaneus in the subtalar. Medial and lateral rotation occurs along the longitudinal axis through the tibia of the talocrural joint (100,105).

2.1.3. Lateral Ligaments

The anterior talo-fibular ligament is perpendicular to the talus in plantarflexion and provides stability against inversion. The calcaneo-fibular ligament is perpendicular to the talus when the ankle is in slight dorsiflexion and provides stability against inversion in slight dorsiflexion (8). The posterior talo-fibular ligament runs from the medial malleolus backward and downward.

2.1.4. Ankle Musculature

The peroneal longus and brevis, with their tendons covering the posterior talo-fibular ligament and part of the calcaneo-fibular ligament, assist in supporting the ankle mortise laterally. These muscles are important for the absorption of stress and provide support to the lateral ligaments (8,46). The tendons that span across the ankle with a long lever arm to the tip of the toes also provide great velocity in movements (42). Peroneal muscles and tendons are mechanically most effective when the person is "on his toe" and are better able to prevent an ankle sprain when the foot is in plantargrade posture (140). Perot et al (1982) in the EMG study of muscular work of the ankle, reported that during abduction of the ankle, the prime mover was the peroneus longus, and a plantarflexion torque appeared simultaneously. This unwanted effort was prevented by the recruitment of dorsiflexor (tibialis anterior) which worked as an antagonist of plantarflexor.

2.2 Biomechanics of Ankle Ligaments

Ankle stability depends on several factors. Besides the bony configuration of the joint itself and the dynamic support from musculatures around the joints, other factors affecting its stability include: the orientation of ligaments, the conditioning of loading on weight bearing, and the position of the ankle at the time of stress (129).

2.2.1. Characteristics of Lateral Ligaments of the Ankle

2.2.1.1. Ligaments for stability

Stormont (1985) reported that for an unloaded (non-weight bearing) ankle, lateral ligaments of the ankle accounted for 87% of resistance to inversion. Of the three lateral ligaments, namely anterior talo-fibular ligament, calcaneo-fibular ligament and posterior talo-fibular ligament, the most important stabilizer for ankle inversion was the calcaneo-fibular ligament, which acted as the primary restraint to inversion. Anterior talofibular ligament accounted for about one-half the resistance that the calcaneo-fibular ligament could take, and acted as a secondary restraint. However, in loaded ankle, no ligament contributed to ankle stability and the restraint was entirely articular. Therefore, the author suggested that ankle instability might occur during loading or unloading but not once the ankle was fully loaded.

2.2.1.2. Ligaments Properties to Loading

Attarian (1985) reported that there were non-linearity and strain rate dependence in load-reflection curves of all ligaments of the ankle. These properties made the ligaments suitable for providing joint stability. It was because at low velocity work such as walking, the ligamentous load in absorbing energy were also low. This provided mechanical efficiency in ankle motion. In high performance situations, such as running or trauma, ligaments bore a progressively (non-linearity) greater load, and increased in energy absorption particular towards the extremes of normal joint motion, thus helped in the prevention of abnormal joint motion.

Cornwall et al (1984) reported that anterior talo-fibular ligament had the lowest maximum load and energy to yield point among all ligamentous structures tested. The deep deltoid which was the least commonly disrupted ligament, had the highest load to failure. There was an increase in elongation and energy absorption of all ligaments prior to their rupture.

Ryan et al (1989) reported in their study that for all ligaments around the ankle, anterior talo-fibular ligament had the lowest maximum load to failure, followed by the posterior talo-fibular ligament. The medial or deltoid ligament had the highest maximum load to failure.

2.3. Lateral Ankle Ligaments Injuries

2.3.1. Etiology

Lateral ankle ligaments injury usually resulted from an inversion force in a combination of various degree of ankle plantarflexion (57). The first component of lateral ankle ligaments coupled to tear was anterior talo-fibular ligament (26,67,100,125). If with pure inversion or adduction force, an isolated rupture of the calcaneo-fibular ligament would result (57).

Injury to the ankle ligaments usually occurred in running, sudden stopping or jumping where the foot landed before the talocrural joint had dorsiflexed to neutral position. The loose-pack position of the foot in plantargrade position would cause a high stress in the anterior talofibular ligament (67,100).

Glasgow et al (1980), in the anatomical study of lateral ligaments of the ankle, they demonstrated that when the anterior talo-fibular ligament was being divided, the instability produced was a forward subluxation of talus in the ankle mortise. The mechanism of common injury to lateral ligaments was: firstly, the rupture of the anterior talofibular ligament, and with the increase in severity, the calcaneo-fibular ligament followed. This explained why anterior instability or anterior subluxation of ankles after inversion sprains, were found clinically more common than varus instability. Diamond (1989) suggested that inversion sprain occurred when there was a sudden force and the ankle did not have sufficient reaction time to response, or the peroneal or tibialis anterior muscles were too weak or too slow to contract in order to counteract the inversion force.

2.3.2. Definition of sprain

Ankle sprain can be defined as stretching the fibers of ligaments or collagen, where the fibers are partially or completely disrupted (18,26,109). This may cause the players to miss the next match or practice session (135). Recurrent sprain is defined as two or more sprains to the ligament complex (50).

2.3.3. Classification of Inversion Ankle Sprain

There is still no standardized system for grading or classifying the degree of severity in ankle sprain (52, 78,79,106,109). A sprain can mainly be classified in two ways. The first way is according to clinical signs and symptoms (13,61,84,98,109), and the second way is according to ligamentous pathology (67,93). These are summarized in Table 2.1 .

2.3.4. Diagnosis of Lateral Ligaments Injury

No specific clinical method has been developed to establish a clear diagnosis of ankle sprain. There is a lack of agreement in diagnostic techniques and an end diagnosis of a particular grade of ankle sprain (52,78, 79,109,113). Anterior draw test and talar tilt test are the two common method used.

2.3.4.1. Anterior Draw Test

This is used to identify the anterior stability of the ankle (16, 30, 48, 87, 172, 177). This test could show the anterior translation of talus with the heel pull forward. Anterior roentogenography or stress X-ray could be taken and the anterior displacement between the posterior tip of tibia and the nearest part of the dome of the talus was measured. However, the normal range of displacement varies from 3mm to 15mm.

	Classification by Clinical Signs and Symptoms	Classification by Ligamentous Pathology
Grade I or mild sprain	- minimal functional loss - minimal swelling - mild tenderness - slightly decrease range of motion	- with microscopic tearing of ligament - with no loss of function
Grade II or moderate sprain	- moderate localized swelling - difficult to toe raise or hop - localized tenderness	- with partial rupture of ligament - with some loss of function
Grade III or severe sprain	- diffuse swelling and tenderness - decrease range of motion - functionally disable (decrease weight-bearing and need the use of crutches)	- complete tearing of ligament - complete loss of function

Table 2.1 Summary of two classification methods in ankle sprain

2.3.4.2. Talar Tilt Test

Talar tilt is done by stressing the talus into inversion, and the angle between the distal tibia and talus was measured with roentgenographic examination (12, 13,14,42,46,47,89,125). However, for this talar tilt test, the talar tilt angle also varies from 4° to 21°.

2.3.4.3. Anthrogram

Anthrogram was said to have a greater accuracy in the diagnosis of rupture lateral ligaments of the ankle by injection dye into the joint capsule (94,100,141). However, this method could only be done in a very acute condition within 24 hours after injury, so that blood clot would not alter the appearance (111). It could not be used in chronic stage because the dye could not seep through a joint that had already fibrous repaired (141).

2.3.4.4. Controversies in Various Diagnostic Methods for Lateral Ankle Ligaments Injury

The diagnostic methods for lateral ankle ligaments injuries vary. Lettin (1963) said that the clinical picture of exact site of pain, swelling and range of motion of the injured ankle could already give a positive and good clinical diagnosis on ankle sprain; stress X-ray was unnecessary and impractical because this might require anesthesia, and any minor degree of change might not be significant. Prin (1978) said that neither anterior draw test nor talar tilt were sufficiently specific to demonstrate a rupture of the lateral ligaments without anesthesia, and their validities were doubtful. Other authors also reported that typical stress film was not necessary because it needed adequate relaxation and required anesthesia; a comparison view with the uninvolved ankle was also required to make a reliable diagnosis (57,61,78,100,128). Some authors reported that an ankle which had a significant increase in anterior displacement or talar tilt would have a higher correlation in functional instability of the ankle joint (10,12,42). Others reported that radiography instability of the ankle did not indicate ankle functional instability or dysfunction (52,80,128,141), or if there was any relationship to frequencies of residual symptoms after inversion ankle sprains. Therefore, the best method for the accurate diagnosis of the degree of sprains is still a debatable matter.

2.3.5. Orthopedic Management of Inversion Ankle Sprain

2.3.5.1. Operative Method

Surgical reconstruction for lateral ankle ligaments rupture was reported to have a good functional result (65,105,110,117). Others reported that there were no statistical significant findings when comparing functional abilities between ankles that had been treated operatively or conservatively. Moreover, few ankle sprains required early surgical intervention (78,94).

2.3.5.2. Conservative Method

In earlier days, a plaster cast for immobilizing ankle was used in the management of inversion ankle sprains (32,94,108). This method however was found to cause ankle stiffness and muscle atrophy. Nowadays, orthopedic surgeons emphasize more on the functional approach in the management of sprains and functional cast bracings or strappings are used, which allow controlled ankle movements to minimize stiffness and muscle atrophy cause by immobilization. Since this management method permits a controlled degree of mobilization, it helps improve the nutritional status of the joint and stimulate healing of the ligaments (17,57).

2.4. Rehabilitation of Inversion Ankle Injury

2.4.1. Residual Problems Resulted from Inversion Ankle Injury

Functional instability of the ankle with the sensation that it could easily give-way is the major complaint of athletes who had sustained ankle sprains (34,35,52,113,127,130,135). Muscle weaknesses, decrease in proprioceptive sense of the injured ankle and calf muscle tightness were the suggested underlying causes for functional instability of the sprained ankle which would lead to recurrent injury.

2.4.1.1. Epidemiology

Chronic residual problems which resulted from ankle sprain were often reported by athletes. These residual problems often affect athletes in their sports performance. Freeman et al (1965) and Rzonca et al (1988) both reported that 40% of their patients with ankle sprain had residual symptoms such as pain, instability and weakness of the injured ankle.

Termansen et al (1979) reported that 20% of his patients with sprain had functional instability of their ankles with a 4.2 years follow-up after their initial injury. Smith (1986) reported that 15% of his basketball players with ankle sprain had residual problems that compromised their playing performance, and 80% of them had suffered recurrent sprain.

Ekstrand et al (1983) in his study on soccer injury reported that 17% of all injuries recorded in a year's period involved the ankle, and 47% of these injured ankles had suffered previous sprains. Ankle sprain was more common for those with a previous history of sprain.

2.4.1.2. Muscle Weakness

Ankle evertors or pronators were often emphasized as muscles for the dynamic back-up of the ankle joint in resisting inversion stress during ankle sprain. Bosien et al (1955) reported peroneal weakness was detected in 23 of the 35 ankles (66%) of college students with chronic instability; and Staple (1975) also reported that with manual muscle testing, peroneal weakness were detected in 43% of symptomatic ankles even with long-term follow-up.

Tropp (1986) tested on 15 subjects with recurrent ankle sprain for their invertor and evertor muscles strength with Cybex II isokinetic dynamometer. He reported that there was a significant weakness ($p<0.01$) in ankle evertor strength tested at 30°/ sec and 120°/ sec. He concluded that peroneal muscles weakness was a component for functional instability of the ankle joint with sprain; and muscle impairment was probably due to secondary muscle atrophy resulting from the injury when there was inadequate rehabilitation for the injured ankle. Linderfeld (1988) said that 50% of his patients with multiple ankle sprains mainly suffered from peroneal weakness but not from ligamentous laxity. He said that only with the support of peroneal muscles, could the ankle resist repeated varus stresses that one encountered in routine sports events. Lateral ligaments alone were not sufficiently strong enough to resist such powerful varus stresses.

Lentell et al (1990) had tested 33 subjects with unilateral functionally unstable ankles on Cybex II+ isokinetic dynamometer at 0°/second and 30°/second. Twelve percent of these subjects had demonstrated a deficit in evertor muscles strength, he suggested further study on the ankle at higher testing velocities because activities involving ankles usually occurred in a closed kinetic chain of which the peroneal muscles contract at very fast speeds in response to high movement velocities.

Termansen et al (1979) tested 124 ankle sprain patients for their isometric plantarflexion strength using strain gauze dynamometer, and reported that plantarflexors strength of the injured ankles were significantly lower than the non-injured side. Gleim et al (1978) reported that pathology in ankle could cause a decrease in lower limb muscular strength.

2.4.1.3. Proprioception

Proprioception deficit was regarded as a cause for functional instability of the sprained ankle. Freeman et al (1965) suggested spraining the ankle would cause a partial de-afferentiation of nerve endings in the joint. He reported that 34% of his patients with ligamentous injury to foot and ankle had proprioceptive disturbance. Lentell et al (1990) reported 55% of subjects with unilateral ankle sprains had balance asymmetry, using a modified Romberg's test (single leg standing with eyes open and closed), but there was no correlation between muscle weakness and balance deficit.

Tropp (1984, 1986), in his stabilometry studies for ankles, variations between line of force in single leg-standing on force plate were measured. No significant difference in stabilometric values was found between the injured and non-injured limbs. Besides, stabilometry was not correlated to muscle strength. However, he found that ankle-disk training could improve stabilometry values and decrease ankle instability. Thus he suggested ankle-disk training could have a central tuning effect on co-ordination with the re-education of position sense and muscle strength. In a preseason stabilometry evaluation for soccer players, Tropp (1984) found that those who had abnormal stabilometric value ran a significantly higher risk of sustaining ankle injury during the following soccer season when comparing players who had normal stabilometry values.

However, Garn et al (1988) reported on a high incidence of balance deficit at the side of an ankle with sprain when standing one-legged. Glencross et al (1981) reported there was an increased error in reposition placing for ankles that were injured severely. The error was caused by a loss of precision in judgment of position sense in the injured ankles and this persisted even for months after injury. De Carlo et al (1986), in his study on proprioceptive sense of ankle joint with the injection of xylocaine to anterior talo-fibular ligament, found that there was an increase in average time in balance following anesthesia injection. But since the timing improved with trails, the authors concluded that anesthesia had no effect on joint proprioception, and joint proprioception could be improved with learning.

2.4.1.4. Peroneal Muscle Reaction Time

It had been suggested that ankle sprain would cause a stretch in joint capsule and muscles. This would lead to slower protective reflexes by the muscles (74,78). Nawoczenski (1985) reported that ankles which sustained previous inversion sprain showed a delay in motor response of their evertors to sudden inversion stress. The injured ankles also showed a greater displacement into inversion than non-injured ankles. Glick et al (1976) reported that in 3 out of 4 subjects with significant talar tilt, their peroneus brevis started to contract before the end of swing-phase. This probably was in an attempt to evert the foot or to stabilize the ankles. Konradsen et al (1990) reported there was an increase in peroneal reaction time to sudden ankle inversion for ankles with sprains, and this increase in peroneal reaction time showed a deficit in peripheral reflex stabilization of ankle.

However, Isakov et al (1986) studied the reaction time of peroneal muscles and found that there was no significant difference in the reaction response of peroneal muscles to sudden inversion stress between the injured and non-injured ankles. He concluded that reflex contraction of peroneal muscles had no role in protecting the ankle joint during sprain The protection was mainly provided by passive tissues.

2.4.1.5. Muscle Tightness

Pain and immobilization after sprain would cause tightness of calf muscles and this tightness often put the ankle joint into a disadvantage position. Staple (1972) reported that a loss of 10° - 15° in ankle motion was found in subjects with ankle sprains. Walsh et al (1977) and Kaumeyers et al (1980) said that ankles with tight heel cord were subjected more to lateral ligament sprains because it limited ankle dorsiflexion and the bowstring effect of the achilles tendons would put the foot into more inversion and plantarflexion.

2.4.2. Rehabilitation Training

2.4.2.1. Muscle Training

Muscular weaknesses, especially ankle dorsiflexors and evertors were often detected after inversion ankle sprain (26,67,74,89,125,135). Any deficiency in muscular strength would often lead to impairment in postural control (74,135). In rehabilitation of ankle sprain, muscle strengthening is therefore essential. Musculatures around the ankle often act as a dynamic support for the lateral ligaments. Strengthening muscles around the ankle could improve reaction time of the muscles to response and counteract inversion force in sprain (82,125). Strong ankle muscles can diminish ankle instability and help supporting ankle mortise (3,8,46). This could break the vicious cycle of recurrent sprain and subsequent muscle atrophy (13,75,78,108,109,135).

Training of ankle dorsiflexors, plantarflexors, invertors and evertors is important, not only in increasing muscle strength, power and endurance, but also in developing muscular balance and increasing joint stability for the prevention of injury and enhancement in functional performance (6,8,85,112). Strength training for the ankle could be done by thera band (8,89,108,125), ankle disk (16,18,85,108,135), progressive resisted exercise (75,85,86) and isokinetic exercise (6,18,26, 41,67,89,125).

2.4.2.2. Proprioception Training

Decrease proprioception and slow protective reflex were noted in those with ankle sprain (27,40,53). Proprioception exercise using balance board (18,82,67, 108) or biomechanical ankle platform (85) were reported to be useful in improving kinesthetic awareness and compensating the peripheral sensory deficit of the ankle (49,51,54,109).

2.4.2.3. Other Training

Stretching exercise to improve flexibility in calf muscle and increase the range of motion in ankle should be included in the rehabilitation programme for ankle sprain and to prevent recurrent sprain (18,61,85,109). Gradual progression training with functional drill should also be given for functional return of athletes to sports after ankle sprain (18,61,85,109).

2.5 Strength Training

2.5.1. Effects of Strength Training

2.5.1.1. On Muscles

Strength training can increase muscle mass, causing muscle hypertrophy and increasing muscle strength. Increase in capillary density in muscles was also found after endurance training (5,20).

2.5.1.2. On Nervous System

Neural adaptation was found following strength training. Bandy et al (1990) reported that there was increase number of motor units and increase firing rate of each unit after strength training, thus resistance training enhanced the ability to recruit additional motor units or discharge the motor units at a faster rate. Sale et al (1983) reported that training could increase reflex potential of motor units and therefore improved the ability of motorneurone excitability to activate muscles during voluntary effort. Rutherford (1988) in his review indicated that neural adaptation of muscles allowed more force to be generated. Kryölainen et al (1989) reported that a prolonged power training of stretch - shortening exercise could result in a specific training - induced effect on knee muscles causing an improvement in neuromuscular performance with an increase in average angular velocities in knee extensor, that was the improvement in explosive power production especially at the first two months of training.

2.5.1.3. On Ligaments

Various authors had reported that strength training could increase the amount of collagens as well as the size of collagen fibers, thus training could strengthen the bone-ligament-bone complex (17,133,139). Tipton et al (1975) reported trained rats had significantly heavier ligament and higher strength between the bone-ligament junction. He found that in his animal subjects, the strength of repaired ligament increased with activity and decreased with immobilization. Vailas et al (1985) also reported in his experiment findings that, the repair of ligaments in rats was facilitated by mechanical stimulation through accelerating the return and uptake of amino acid , thus accelerating cellularity .

2.5.2. Isokinetic Training

Isokinetic means constant velocity or speed, of which movement of part(s) of the body is being controlled at a preset velocity. Any movement faster than the preset velocity would not be allowed. Isokinetic movement can only be provided by specially made isokinetic machines. Velocities of movement is ranging from 0 degree per second to 300 degree per second or even higher, depending on various models of machines. Movement speeds slower than 120 degree per second are defined as slow speed and speeds faster than 120 degree per second are defined as fast speed movements (105).

Isokinetic exercises have been reported as an effective method in muscle strengthening, both in peak torque development and in endurance training, depending on the training velocities (4,85,109,124,131,132,142).

Moffroid et al (1970, 1990) in his studies reported that high speed isokinetic training could increase muscle force at or below the training speed and improve muscle endurance at high speed; while slow speed isokinetic training could improve muscle force at slow speed. Coyle et al (1981) also reported that fast speed isokinetic training could improve peak torque at all speeds, there was a carrying-over effect from higher velocity to slower velocity.

In the study by Smith et al (1981), he reported that isokinetic slow speed training could increase muscle force in slow speed, while high speed training could increase peak torque in high speed and to a much greater extent than using slow speed training. Moreover, high velocity training could also improve motor performance (including stand board jump, standing vertical jump and 40 yard dash). Baltzopoulos et al (1989) in his review said that the improvement in muscular performance following isokinetic training could be explained by velocity-specific adaptation of motor units within the muscle and velocity-specific adaptation within the nervous system.

Jenkins et al (1984) reported that the carrying over effect in isokinetic training was in both directions of the training speed, and fast velocity training would increase strength at every testing velocity. Davis (1985) reported of an overflowing effect of at least $\pm$ $60°$ per second in isokinetic training.

Perrin et al (1989) also reported that high speed training not only had an overflowing effect to slower speeds in peak torque measurements, but was also effective in increasing torque acceleration energy. Grimby (1984) said that training at high movement velocities could cause a greater improvement in developing muscle tension with the training of fast twitch fibers. Besides, training muscles at various angular velocities was important in increasing the specificity of training at certain phase of rehabilitation. Barnes (1980) said that isokinetic training at various contractile velocities were required for different neurological recruitment thus enhancing muscle function.

Vitti et al (1984) suggested the greater increase in strength following high speed isokinetic training could be the result of increasing in muscle fibers recruitment and/or fast speed training would bring about a more synchronous firing of motor units.

Timm et al (1985, 1987), using velocity spectrum in isokinetic training programme, reported that all measurements in peak torque, torque acceleration energy and average power were increased after training. There was an overflow effect of at least ± 120°/sec. This overflow effect in training with speeds overlapping across velocity spectrum could reinforce the training effect.

Knapik et al (1983), comparing strength training with isokinetic and isometric exercise for elbow flexor, found that isokinetic exercise groups had a significantly greater improvement than the isometric group. Isokinetic effect could also be transferred to isometric force but not vice versa. Several other studies making comparisons between strength gain from isokinetic and isotonic exercise concluded that isokinetic training could increase strength to a greater extent than isotonic training (145).

III. METHODOLOGY

This study on the isokinetic rehabilitation of ankle sprain was divided into 3 major stages. All subjects in this study were Hong Kong Chinese athletes.

At the first stage, an epidemiological survey was conducted among the local Chinese athletes who had previous history of ankle sprain(s) to either one or both of their ankles.

The second stage was isokinetic testing for normal subjects without a history of ankle injury. Subjects were tested with the isokinetic machine for obtaining various muscular parameter data of the ankle. The muscle groups involved were the ankle dorsiflexor and plantarflexor, ankle invertor and evertor. The tested subjects must fulfill the following criteria: (1) they have never had or recalled any injury to their ankles or feet; (2) there was no major injury to their lower limbs; and (3) they had no major disease(s) affecting both of their lower limbs. This isokinetic data obtained would be used as a baseline or a norm for the studying of normal variation of muscular parameters between the dominant and non-dominant legs' ankles, and serve as a guideline for comparing data between various muscular parameters of the injured (sprained) and uninjured (normal) ankles at a later stage.

The third stage of the study was further sub-divided into 3 phases. At this stage, the subjects must fulfill the criteria that they all had previous history of uni-lateral recurrent ankle inversion sprains of either ankle while the other ankle was normal and injury free. The first phase included: (1) assessment of ankle joints; (2) first subjective rating with the ankle functional scale questionnaire, and (3) isokinetic evaluation of both ankles using the same protocol and settings as in the second stage. In the second phase, half of the tested subjects with unilateral ankle recurrent sprains received an isokinetic training programme , while the other half served as the control group. The third phase was a retest for all subjects including: (1) isokinetic re-evaluation for ankle using the same testing protocol and setup, and (2) second subjective rating for all subjects with the same ankle functional scale question-naire. The procedure and stages of study were summarized in figure 3.1 in the form of a flow chart.

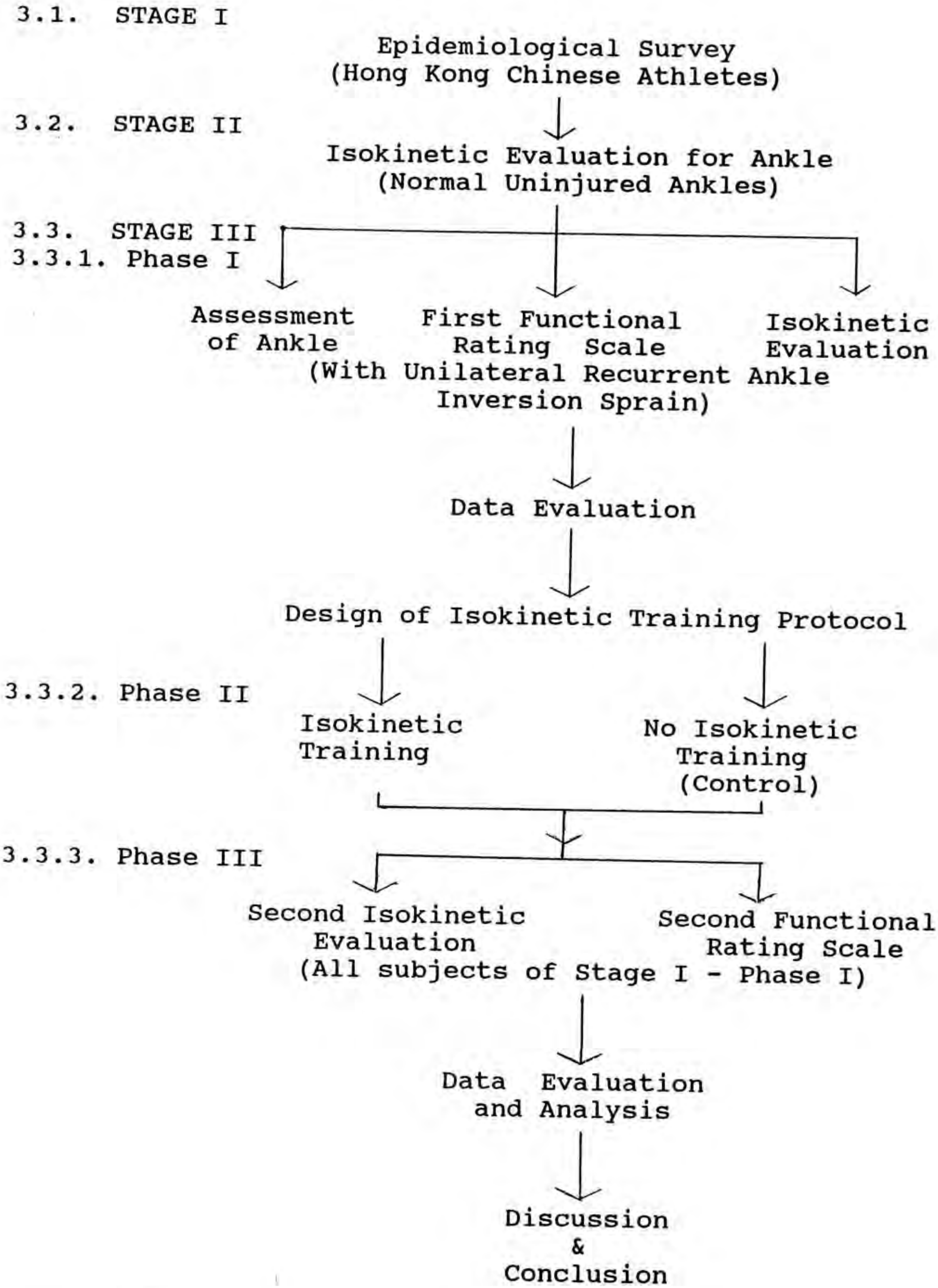


Figure 3.1. Different Stages of Study

3.1. Epidemiological Survey

Chronic ankle problems with residual symptoms of chronic muscular weakness, decrease in proprioceptive sense of ankle joint, and chronic ankle instability in which the ankle easily giving-way were often reported following ankle sprains (10,17,26,35,52,74,108,109,125, 128,130,135).

Although locally in Hong Kong, there had been epidemiological studies on various patterns of sports injuries among the sportsmen, there were no published study about ankle injuries. In order to obtain up-to-date information about how frequently recurrent ankle sprains occur among local Hong Kong Chinese athletes; how often athletes have residual ankle symptoms; and to what extent athletes regard these problems as an interference with their sports performance, a survey on the epidemiology of ankle sprain was carried out. This survey could also help the investigator in identifying appropriate subjects for ankle assessment and rehabilitation training at a later stage.

3.1.1. Design of Questionnaire

The questionnaire was divided into three parts. The first part included demographic data, such as age, sex, leg dominance. The second part was about sports related data. The third concerned mainly ankle sprain and its related effects.

In order to avoid bias or misinterpretation and to cut down answering time, the questionnaire was so designed that most questions were close-ended questions which required only a tick to the most appropriate option.

3.1.2. Pilot Study

A pilot study was carried out among some staff members and athletes in the Hong Kong Sports Institute to find out if the format was clear and effective. The questionnaire was improved and the revised version was prepared bilingually. A total of 17 questions had to be completed by all subjects who had either unilateral or bilateral ankle sprains. Those who had bilateral ankle injuries had to complete answers for both left and right ankles. In general, the entire questionnaire could be completed within 12 minutes.

3.1.3. Survey

The subjects of this study were mainly athletes who involved in sports activities on a regular basis; they could be competitive athletes or recreational athletes. All the athletes must have at least sprained their ankles once with detectable swelling and pain around the ankles. Subjects with ankle sprains for less than 3 months were excluded, since these acute injuries would give rise to pain and swelling and might not indicate the true pattern of chronic ankle problems. The sprains were occurred during sports activities. Most athletes were from the Hong Kong Sports Institute and sports clubs. The survey was conducted at sports fields where athletes were having their training. The questionnaires were distributed by the investigator or coaches of a particular sports team either before their training session or in between rest period and all questionaires had to be returned immediately. Previously an explanation was given to the coaches about the criteria of subjects to be chosen and they were asked to check that all questions were completed in order to avoid errors. A total of 400 questionnaires had been sent out.

Please refer to appendix I for the questionnaire.

3.2 Isokinetic Evaluation for Normal Non-injured Ankle

Subjects with no previous bilateral ankle injury history were tested with the isokinetic machine for obtaining normative data of their ankle muscles parameters. Normative data are important because they serve as guidelines for testing and/or rehabilitation and setting training goals (102). An isokinetic machine is an effective testing tool that can improve the objectivity of measurements (89).

3.2.1. Subjects

(1) Criteria

(a) Subjects for normative data evaluation have recall no previous history of ankle and foot injuries. There were no major injuries to their lower limbs and no major disease affecting their lower limbs

(b) All subjects were Hong Kong Chinese. This is to ensure the least discrepancy between different races. In this study, the age range of 15 - 40 years was selected because this was the most active group in the community.

(c) Source

The main source of subjects were students from the

Chinese University of Hong Kong, physiotherapy students from Hong Kong Polytechnic and physiotherapists in Hong Kong.

3.2.2. Equipment

The Cybex II+ isokinetic dynamometer (Cybex Division of Lumex, Inc, NX 11779) was employed as the evaluation tool in this study. Together with the dual-channel recorder which uses the Cybex II+ chart data graph to record torque curve and position angles during test, and with the Cybex Data Reduction Computer (CDRC), dynamic torsional forces at various preset velocities could be recorded throughout the entire tested range of motion. For the testing of ankle musculatures, the upper body Exercise Table (UBXT) was used for positioning of the subjects. (Picture 3.1. and 3.2)

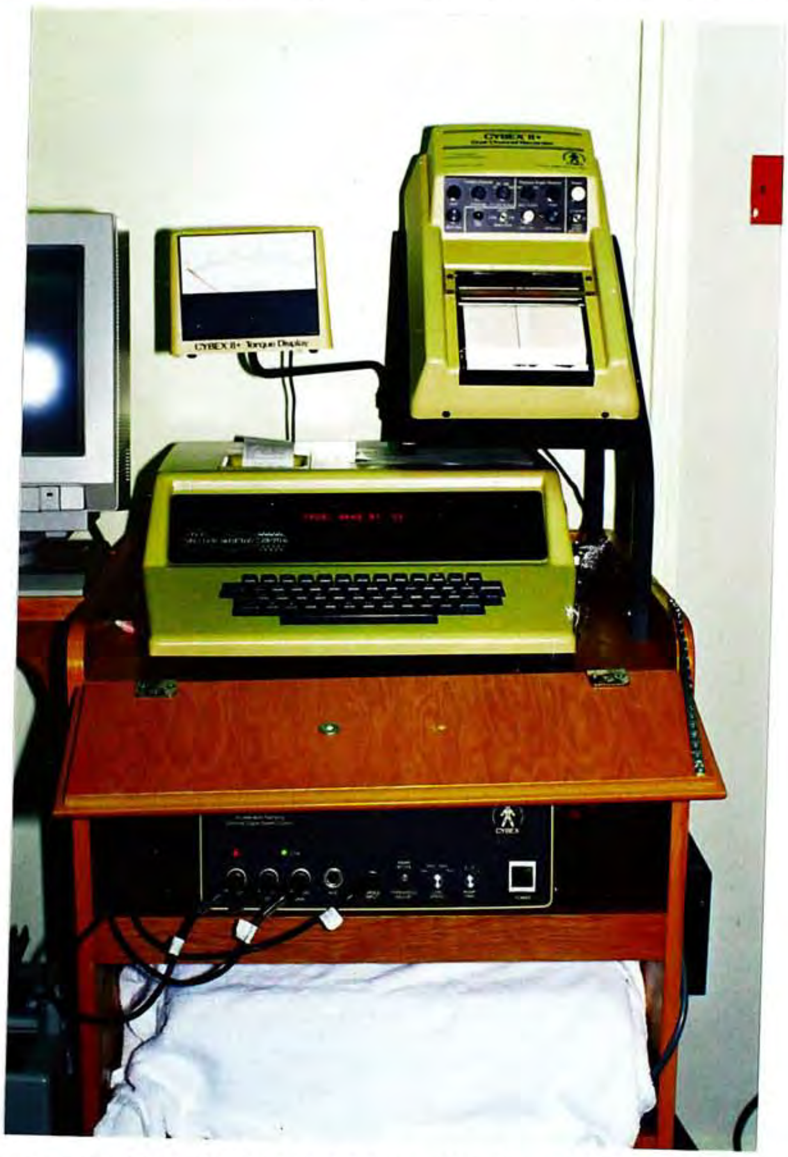
(1) Parameters of testing

The Cybex Data Reduction Computer (CDRC) could print out various parameter data onto the computer recording sheet. Parameters that were commonly used in tests include:

(a) Peak torque

It is the absolute maximal force produce during an isokinetic contraction at a preset velocity.

Picture 3.1 Cybex II+ Isokinetic Dynamometer with Upper Body Exercise Table



Picture 3.2 Cybex Data Reduction Computer with Dual-channal Recorder

(b) Peak torque body weight ratio

It is a ratio between the peak torque and body weight. Since body weight among individuals varies, thus making comparison of absolute maximal muscular performance impractical. Peak torque body weight ratio could be used as one of the main parameters for comparison of muscle forces between individuals (145).

(c) Peak Torque Acceleration Energy (PKTAE)

This is a measurement of the "explosiveness" of a muscle contraction. It measures the total amount of work in the first 1/8 of a second of a contraction.

(d) Total work output

It is the total amount of work performed from the total number of muscle contractions.

(e) Average power

It is the measurement of total work energy divided by the time required to complete the work.

(2) Testing Speed and Repetition

Two testing speeds were selected for this study, including a slow contractile speed at 60°/ sec and a fast contractile speed at 180° /sec. 60°/second which is a relatively slow speed for ankle activities was chosen for obtaining peak torque value (111). A relative fast speed of 180°/second was selected because most of the functional limbs speeds exceed 90°/second or even exceed 240°/second, thus it is more related to actual function (161). Mawdsley and Knapik (1982), Magee and Currier (1988) said five repetitions of reciprocal muscle contraction at maximal contraction force were required. A fast functional velocity of 180°/ sec was selected as endurance testing speed and 25 repetitions of reciprocal contractions at maximal force throughout the entire contractions were required. At this fast speed, peak torque, peak torque body weight ratio, torque acceleration energy, average power, and total work values were obtained. The test speeds chosen were also recommended by the Cybex manufacturer for obtaining the most reliable measurements.

(3) Reliability of Cybex II+ Isokinetic Testing

In any testing, it is important that the testing protocol utilized is reliable and there is consistency in the testing results. The within subject variation is low so that any detectable changes in performance could be attributed to the experimental intervention. When a test is reliable, one can confidently rule out test - retest variation as an explanation for changes in performance and one can assume that the error components are random, uncorrelated and independent.

Karnofel et al (1989) in his study of the reliability of isokinetic muscle testing of the ankle, peak torque at 60°/ sec and 120°/ sec for ankle dorsiflexion and plantarflexion, inversion and eversion were measured at 3 separate test sessions. He found that with a proper warm-up, substantial increase in peak torque did not occur. The interrater and intrarater coefficients were high for all four groups of muscles at the two test speeds (correlation ranging from 0.84 - 0.94). He concluded that the test was reliable and had no evidence of significant increase in torque values across repeated test sessions due to learning effect.

Montgomery et al (1989) studied on the reliability of isokinetic test on knee muscle strength and endurance. He found that there was high interclass correlation coefficients in total work and average power, and there was no test day effect. However, endurance ratio measurements were low in interclass correlations. Therefore, total work and average power would be used for evaluation in this study.

Leslie et al (1990) studied on the reliability of isokinetic torque values for ankle invertors and evertors at 30°/sec and 120°/ sec test speeds, he reported high reliability in Cybex test - retest scores and suggested consistency in the testings. He also reported the use of "targets", as markers to exhibit the range of movement of ankle inversion and eversion, would cause an improvement of 50% in reliability in the target group than non - target group.

Byl et al (1991) in the study on reliability on isokinetic measurement reported that there was consistency in testing if subjects were tested and retested with the same protocol, with the same machine, at the same site and by the same examiner or a different examiner.

As a summary, isokinetic testing is reliable when the same examiner and the same machine are used. Together with a proper warm-up and consistency in verbal encouragement, it was proven to have a high degree of reproducibility between successive attempts.

3.2.3. Testing Procedure

Each subject had to come to the Sports Medicine Department, Hong Kong Sports Institute on two separate days for the testing of two different ankle movement patterns. The first session was for the testing of ankle dorsiflexion/ plantarflexion (DF/PF) and the second test session was for the testing of ankle eversion / inversion (EV/INV).

(1) Preparation of subject

Subjects were required to dress simple T-shirts, shorts, socks and tennis shoes. Personal data such as name, sex, age and range of motion of active and passive ankle dorsiflexion were recorded on the first day of testing. Goniometer was used for measurement of ankle dorsiflexion range. The subject was sitting on a couch while actively dorsiflexing the ankle fully and the angle of the motion was measured with one arm of the goinometer along the fibular bone and the other arm along the 5th metatarsal of the foot (97). Passive ankle dorsiflexion was taken when subjects were passively dorsiflexing the ankle in a standing position. (Picture 3.3 and 3.4)

To ensure maximum effort from all subjects, the purpose of the testing, details of the testing procedures and the significance were explained. Written consent was given, signed and returned before the testing (Appendix II).

Picture 3.3 Measurement of Active Range of Ankle Dorsiflexion

Picture 3.4 Measurement of Passive Range of Ankle Dorsiflexion

(2) Pre-test Warm-up

Before each testing session, the subject was required to do a fixed set of warm-up exercises, which included cycling and stretching. The Monark Cycling Ergometer which was set at 1 W/Kg (99) for 10 minutes was followed by 5 minutes of stretching exercises to the lower legs. The warm-up exercise was important in the prevention of musculoskeletal injury and to prepare the subject for the test (122).

(3) Testing Protocol

The testing protocol was listed as below (Table 3.1).

Test Speed	Ankle Motion	Repetition	For
60°/sec	DF/PF	5	Peak Torque
	EV/INV	5	Peak Torque
180°/sec	DF/PF	5	Peak Torque
		25	Work
	EV/INV	5	Peak Torque
		25	Work

Table 3.1 Isokinetic Testing Protocol for Ankle Dorsiflexion/Plantarflexion, Inversion/Eversion

(4) Actual Testing

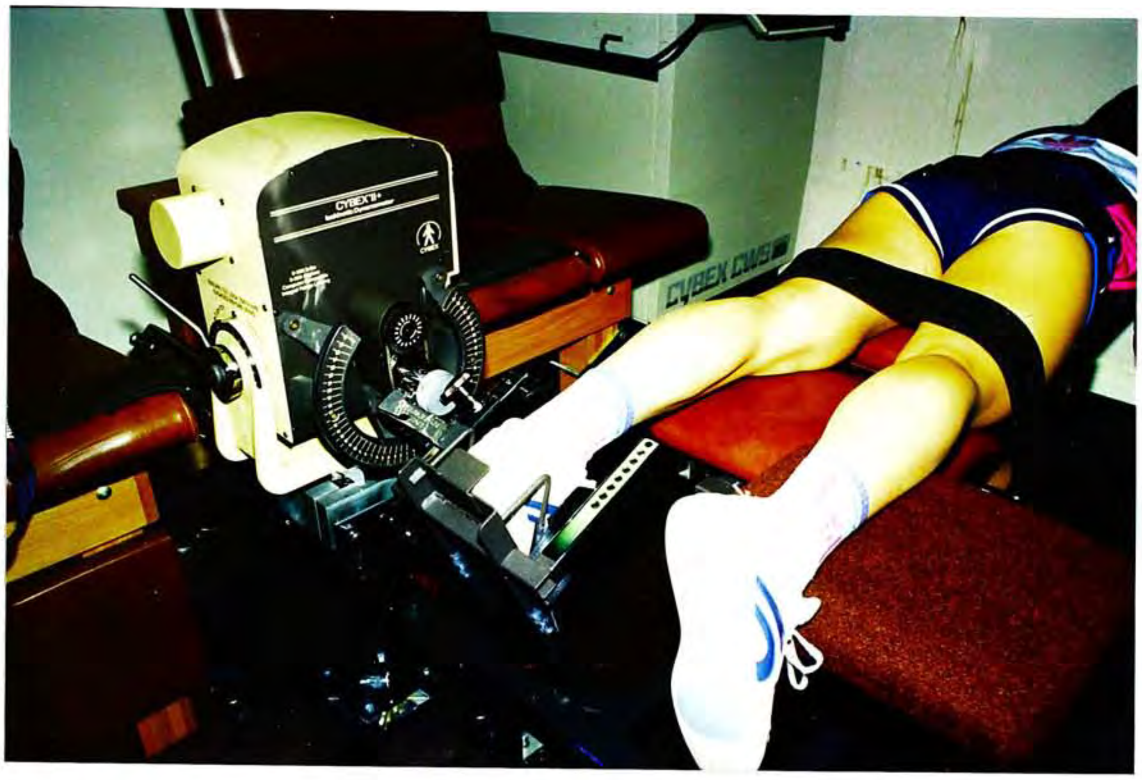
(a) Set-up and positioning

(i) For ankle dorsiflexion/ plantarflexion

The subject was positioned in prone for the testing of ankle dorsiflexion/plantarflexion (with knee extended). The foot of the tested ankle was strapped onto the plantar/dorsiflexion foot-plate. The subject was positioned that the hip was slightly internally rotated to approximately 16° so that the axis of movement at the talocrural joint was aligned with the axis of the dynamometer. The foot was placed flat on the foot-plate enabling the foot to assume a neutral position, ie. neither inverted nor everted. The pelvic strap was used to stabilize the upper-leg just above the knees. An additional torso strap was used for the fixation of the upper trunk. This setting position was in accordance with that suggested in the Cybex isolated joint testing and exercise handbook (60). (Picture 3.5)

(ii) For ankle eversion/ inversion

The subject was positioned in a supine posture with the upper body exercise table seat in its highest position. The dynamometer head was tilted back 55°. The tested ankle was placed on the inversion/ eversion foot-plate. The subject was positioned so that the ankle was



Picture 3.5 Positioning for Isokinetic Testing for Ankle Dorsiflexion/Plantarflexion

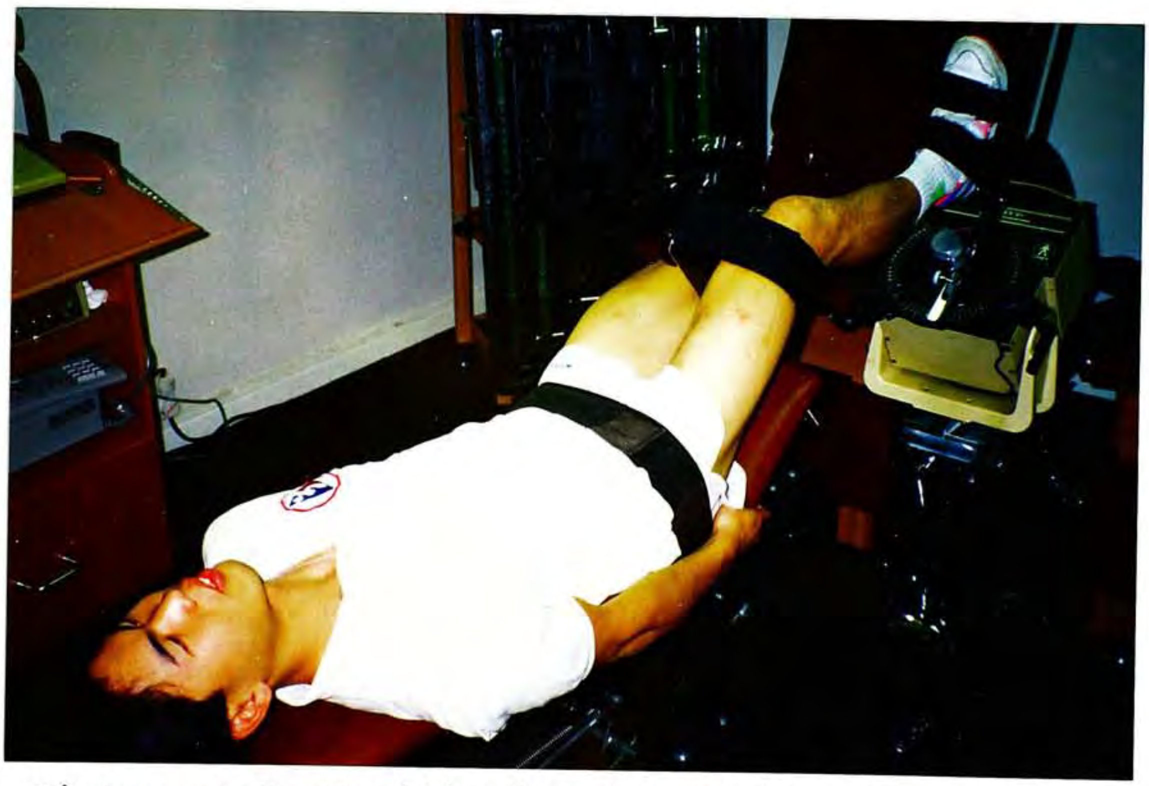
in a complete neutral position (0° plantarflexion/ dorsiflexion and 0° inversion/ eversion, by palpation of the head of talus in neutral position. The knee of the tested ankle was stabilized with the inversion/eversion input adaptor, and was flexed between 30° - 75°. The dynamometer axis transected the superior edge of lateral malleolus (Picture 3.6). The setting was positioned according to the Cybex isolated joint testing and exercise handbook, except 2 stoppers were used to limit the range of motion of inversion and eversion and prevent excessive tibial rotational movement and to assist the subject in determining the range of movement especially in the endurance test (75) (Picture 3.7).

The subject was instructed to move the ankle into inversion and eversion without pushing against the footplate with hip and knee extension forces. Adjustment was made if excessive tibial rotational movement was noted. The subject's pelvic was stabilized with the pelvic strap.

(b) Instruction to subjects

After positioning the subjects, they were asked to move the limb through the whole range of motion if the limb was comfortable and minor adjustments were made to

Picture 3.6 Alignment of Ankle Axis with Machine Axis for Testing of Inversion/Eversion



Picture 3.7 Positioning for Isokinetic Testing of Ankle Inversion/Eversion

the strap according to the subjects' comfort. Subjects were instructed to exert maximum effort throughout the whole test. For peak torque test at 60°/ sec, there was no verbal encouragement given. For work test at 180°/ sec, subjects were asked to exert maximum force throughout the total repetitions without letting go in any part of the test. Throughout the total of 25 repetitions in work test, subjects were encouraged twice with "good, keep going" at the 10th and 20th of their reciprocal contraction respectively.

(c) Warm-up and test

3 sub-maximal and 3 maximal contractions were used as warm-up on the machines for the subjects to familiarize with the machine at each test speed. A one minute rest interval was given in-between warm-ups and the test, and between two different speeds of testing movements. The non - dominant leg's ankle was first tested. The dominancy of the leg was determined by the one used to kick a ball through 2 goal posts (74,75,145).

3.3. Evaluation for Ankles with Inversion Sprain

In this part of the study, subjects with unilateral recurrent ankle inversion sprains were defined as subjects in the "injury group". They were evaluated isokinetically as well as functionally. There were three phases in this part of the study. The first phase included an isokinetic evaluation for ankle and an questionnaire on ankle functional rating scale which was designed for the subjective functional assessment of the ankle. The second phase was isokinetic training for sprained ankle, and the third phase was isokinetic re-evaluation and the second ankle functional rating scale.

3.3.1. Initial Evaluation

3.3.1.1. Criteria for subjects

(a) All subjects had previously sustained unilateral recurrent ankle inversion sprains. At the time of testing, there must be at least a lapse of three months since the last sprain, for maturation phase in soft tissue healing starts around three weeks after injury, and time is required for the soft tissue structure to reach near-normal level of strength (55). Furthermore, there was no acute pain around the ankles and required no more treatment. Since controversies existed in the grading of ankle sprain (78,79,84,109), in this study, ankle sprains were defined according to clinical signs and symptoms

(13,61,84,109). The subjects must have recalled at least two incidents of ankle inversion sprains with pain and swelling over the lateral aspect of the ankle and limitation in their activities after the sprain.

(b) The subjects were athletes of various sports clubs with regular training in their respective sports.

(c) The subjects must be free from other types of injury to the lower limbs except unilateral recurrent ankle sprains.

(d) The subjects must be free from any diseases which affect the lower limbs.

3.3.1.2. Interview of subjects

An initial interview was arranged for each subject. The exact history of injury, the site of injury, and the present condition of their ankle were recorded. Any subject who failed to meet the above criteria were eliminated from this study.

3.3.1.3. Testing Procedure

All testing protocols and procedures were the same as those for normal subjects, except each athlete had to answer an ankle function rating scale questionnaire, and an anterior draw sign test of the ankle was performed manually by a doctor. The same doctor carried out the draw test for all subjects.

(a) Ankle Functional Rating Scale

This was a subjective rating system designed to evaluate athletes' ankle symptoms in relation to their sporting activities.

Since there was no available comprehensive functional assessment scale of this type for assessing athletes' sports performance with chronic recurrent ankle sprain, an ankle functional rating scale was designed. It was based on pain, swelling, stability, and activity level that the athletes reported (61). Grace (1985) said that normalcy of an isokinetic measurement or muscle imbalance was important only when it was related to actual injury or at least a functional performance.

This scale was based on Weber's ankle rating protocol for ankle fractures (Hughes et al 1979), functional rating of ankles (Seligson et al 1980) , clinical scoring system for ankle fractures (Phillips et al 1985) and Cincinnati rating system for anterior cruciate ligament insufficient knee (Noyes et al 1984). The ligament insufficient knee (Noyes et al 1984). The structure was modified by excluding questions such as limitation in range of motion, radiological findings, walking disability, etc which mainly affected those with an ankle fracture rather than a sprain. More emphasis was placed on the functional aspect of the athletes, for example, jumping and running.

This ankle functional rating scale was an subjective rating system (Appendix III). It was a numerical rating system which independently evaluated seven various aspects of ankle symptoms and functions. The questions included: pain (20 points), swelling (10 points), instability (20 points), tightness (10 points). This system also emphasized on the functional return in relation to high level sporting performance. Therefore, there were 3 questions which were specifically directed towards identifying the ankle functional level including: overall ankle function (20 points), running (10 points) and turning/ twisting (10 points). The total score was 100 points.

The questionnaire was designed both in English and Chinese so that the Hong Kong Chinese athletes would easily understand all the questions.

The questionnaires were distributed to all subjects in the first isokinetic evaluation of ankles and also in the re-evaluation session. The subjects were required to "tick" the most appropriate answers in respect to their ankle function at the time of the assessment and points were allocated to each answer accordingly.

(b) Anterior Draw Test for Ankle

The diagnosis of ankle sprain was usually based on the history of injury and clinical examination. No specific method has been developed to establish a definite diagnosis, nevertheless, the anterior draw test was one of the methods of choice (79). Hacdenbruch et al (1979) said it was a sensitive method for detecting lateral ligament rupture. Landeros et al (1968) said anterior ankle instability was much more common than talar tilt, and Laurin et al (1975) said the anterior draw test could make a diagnosis of serious ligamentous injuries in spite of absence of talar tilt. The anterior draw test was comparatively more accurate diagnosis of instability because the torn anterior talo-fibular ligament precedes the torn anterior talo-fibular ligament and calcaneo-fibular ligament.

The anterior draw test was performed with the subject's heel rested against a contact support. One hand of the examiner held the subject's ankle in slight plantarflexion position, while the other hand was placed over the distal part of the ligament. A distraction force was applied to the joint with the subject relax as much as possible (Frost et al 1977).

In this study , the test was carried out by a medical doctor who had not been informed which ankle was injured in order to eliminate any bias. The result was reported as: (1) no laxity detected, or (2) laxity detected when comparing both ankles.

(c) Range of Motion of Ankle Dorsiflexion

Calf muscle tightness was often mentioned as a predisposing factor for a recurrent ankle sprain (128, 143). The range of movement of active and passive ankle dorsiflexor was measured and bilateral comparison was made.

(d) Isokinetic Testing

All subjects were tested for ankle dorsiflexion, plantarflexion, inversion and eversion using Cybex II+ isokinetic dynamometer. The same testing protocol, warm-up procedure, set-up for isokinetic testing of the ankle, and instruction were given for all subjects in the injury group as in the normal group.

The non-injured ankle was first tested, followed by the injured (sprained) ankle. All subjects must have no pain during any of the testing movements, as pain might affect the maximum effort from the subject and the true values in muscular data would be altered. Therefore any subject with pain during the testing were excluded from this study, in order to avoid unreliable data of "weakness".

3.3.2. Training Program

3.3.2.1. Subjects

Half of the subjects from the injury group were randomly assigned as the training or exercise group, and the other half served as the control group or the non-training group. The training group received isokinetic exercise training for ankle dorsiflexion/ plantarflexion and ankle inversion/ eversion. All subjects continued their daily activities and their usual sports activities.

3.3.2.2. Various Methods of Training or Exercise

(a) Types of Strengthening Exercise

1. Isometric exercise or static exercise

It is the form of exercise where muscles contract and muscle tension increases with no relative displacement at the joint movement. The velocity of movement is held constant.

2. Isotonic exercise

It is the form of exercise where the muscle changes its length as it contracts, there is constant muscle tension with displacement of joint movement. If the length of muscle shortens as it contracts and displaces, this is concentric isotonic contraction. If the muscle lengthens as it contracts, for example, the quadriceps muscle works when a person walks down the stairs, this is called eccentric isotonic contraction.

3. Isokinetic exercise

It is the form of exercise where the movement is against a preset speed, that is, velocity of motion is held constant and controlled. The resistance is not set, its resistance is equal to the muscular force applied, and varied according to the effort that the subject applied (85,102).

(b) Isokinetic Verses Other Forms of Exercise

Isokinetic is a speed specific form of exercise. Knapik et al (1983) reported that both isokinetic and isometric training could improve strength, however, the isokinetic exercise group had improved in strength significantly more than the isometric exercise group, and strength gain in isokinetic training could be transferred to isometric forces but not vice versa. The authors explained that in a dynamic task, strength training might involve motor learning in the firing of a number of motor units in proper sequence or coordination to achieve maximal force. Isokinetic training might have achieved this coordination, but not isometric training due to its static nature.

Smith et al (1981) in his study found that subjects trained isotonically and isokinetically at both slow and fast speeds had all increased in muscle strength, however, subjects who trained at high speed had a significantly much higher increase in peak torque at high speed and there was improvement in the motor performance including stand board jump, stand vertical jump and 40 yard dash. This was not shown in the isotonic exercise group.

Fleck et al (1983) in his review reported that isokinetic training increase strength to a greater extent than isotonic training, so isokinetic contraction was preferred over isotonic contraction for strength development. At fast speed isokinetic training, there was a greater increase in motor performance than isotonic training. When compared with isometric training, isokinetic training was also preferred over isometric training for strength development. McInerney et al (1988) suggested that in isokinetic training, there was reflex relaxation of agonist and antagonist muscle groups which allowed for maintenance of maximum blood flow through the muscles during exercise. Grimby (1985) reported isokinetic training could cause maximum load through the full range of motion.

3.3.2.3. Isokinetic Exercise Protocol for Ankle

(1) Choice of Training Speed

Various studies had reported that isokinetic exercise was an effective means for muscle training since isokinetic could train the muscle with maximum loading throughout the full range of movement (33,49,68,85,124). Studies had shown that slow speed isokinetic exercise could improve peak torque at slow speed significantly (

31,124). High speed isokinetic training could improve peak torque at high speed significantly as well as torque below training speeds (20,28,31,87,88,103). Therefore, there was a carry over effect from high speed training to slow speed. Timm et al (1987) in his study reported that there appeared to be an overflow effect of at least ± 120°/ sec in isokinetic training.

Moffroid et al (1990) reported that high speed training could improve muscle endurance more than slow speed training. Perrier et al (1989) and Smith et al (1981) both reported that fast speed training not only could improve peak torque produced by trained muscle group, but also could be effective in increasing the torque acceleration energy and average power of the trained muscles. Smith also reported that fast speed training could improve not only muscle strength but also motor performance. Coyle et al (1980) found that fast muscular power could only be improved by including fast speed training.

(2) Velocity Spectrum Training

Jenkins et al (1984) reported that in isokinetic training, significant strength gain was observed at the training speed and a carry-over effect might be elicited at a velocity faster or slower than the training speed. However, this carry-over effect was insufficient to replace specific speed training and velocity spectrum training of which training at various speeds of movement could be an effective means in training muscles.

Timm et al (1985, 1987) suggested overflow effect between specific speed could promote an optimal neuromuscular response and an overflow effect could serve to reinforce isokinetic effect at each treatment velocity.

3.3.2.4. Design of Training Protocol

Baltzopoulos et al (1991) suggested that rehabilitation velocity from 60° - 300°/second should be included to ensure both muscle fiber types were recruited. Sherman et al (1981) said that principle of training programmes should encompass slow, medium and high speed training.

In this study, a velocity spectrum training protocol was utilized for the training of subjects with recurrent ankle sprains. The protocol was designed in such a way that subjects were trained 3 times per week for a total of 6 weeks (19,20,21,22,23,87,88,124).

The training speed starts at 60°/sec through 240°/sec with 60 degrees interval. Since 10 or 20 repetition exercise sets were found to increase peak torque, average power and total work significantly (21,22,23), 10 repetitions at each training speed up the velocity spectrum and then downward were employed as the exercise protocol in this study (Table 3.2). There was one minute rest between each training velocity.

The subjects worked on ankle dorsiflexion/ plantarflexion first and rested for 30 minutes before working on ankle eversion/ inversion.

Speed (°/sec)	Repetition
60	10
120	10
180	10
240	20
180	10
120	10
60	10

Table 3.2 Exercise Protocol for Ankle Dorsiflexion /Plantarflexion, and Inversion/ Eversion

3.3.3. Second Evaluation

3.3.3.1. Subject

(1) All Subjects who had attended the initial evaluation were requested to be back for the second evaluation.

(2) The second evaluation was done 8 - 10 weeks after the initial evaluation. So the exercise group had the re-test done 2-4 weeks after their training and the non-training group had their re-test done at a similar time interval between the initial evaluation and second evaluation.

3.3.3.2. The Re-test

(1) Second ankle functional rating scale

The same functional rating scale questionnaire was distributed to the subject on the day of second evaluation. The subjects were requested to fill in the questionnaire according to their present functional performance of their sprain ankle.

(2) Isokinetic Re-evaluation

The second isokinetic evaluation followed exactly the same set-up, the same testing protocol, and the same procedure as the initial assessment.

3.4 Data Analysis

The epidemiological data and isokinetic data were all entered and stored in database IV.

SPSSPC +V3.0 Chicago, Illinois (1989) was used in statistic analysis for isokinetic data. Paired t-test was used for analyzing data between dominant and non-dominant ankles and pre and post training data. T-test was used for analyzing data between male and female.

Statistics with Finesse was employed, with chi-square used for comparing the pre and post evaluation of ankle function rating scale.

Lotus (version 2.2) was employed for graphic presentation of data results.

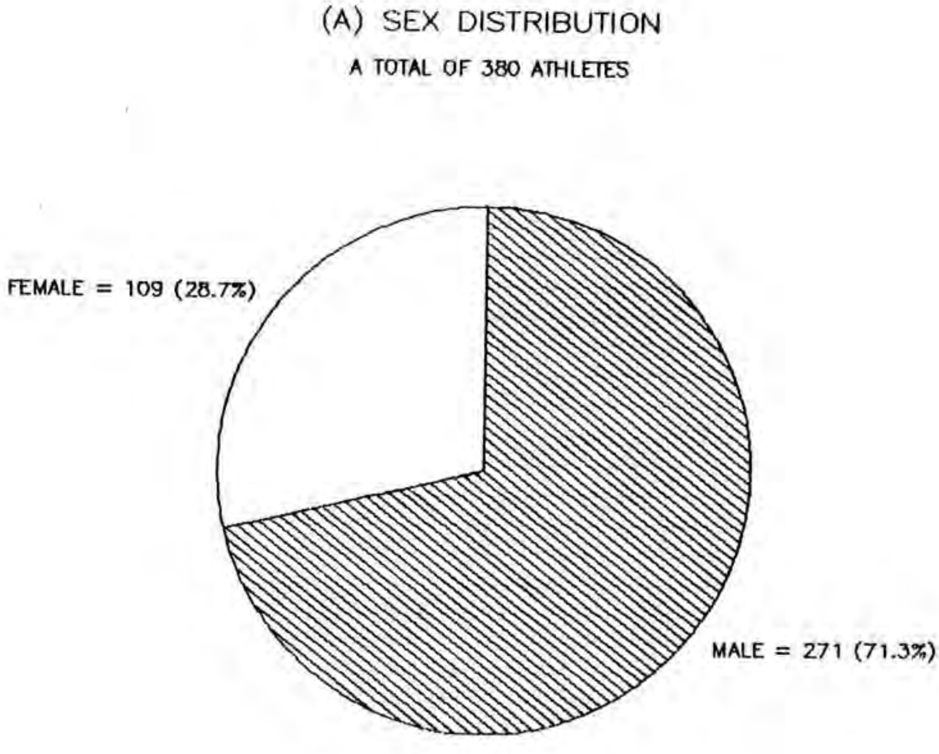
IV. RESULT

4.1. Epidemiological Study

The questionnaires were administered to athletes between June 1990 to June 1991. They were distributed to athletes who had previous history of ankle sprains on site of sports fields or courts, and were collected immediately after being filled in. Therefore, the returning rate for the questionnaires were 100 percent. However, 20 of them had incomplete answers, leaving 380 completed questionnaires for data analysis.

4.1.1. Athletes' Personal Data

A total of 380 athletes' data were available for analysis. Of these 380 athletes, 271 were males and 109 were females (Figure 4.1A). Their mean age was 24.57 years (range 13 - 47). 19 different sports were recorded as the athletes' priority sports. These included: 93 in running activities (track, marathon, orienteering), 77 in racquet sports (tennis, squash, badminton), 54 in soccer, 72 in ballgames basketball, volleyball, etc.), 23 fencers and others (table-tennis, gymnastics,etc) (Figure 4.1B).



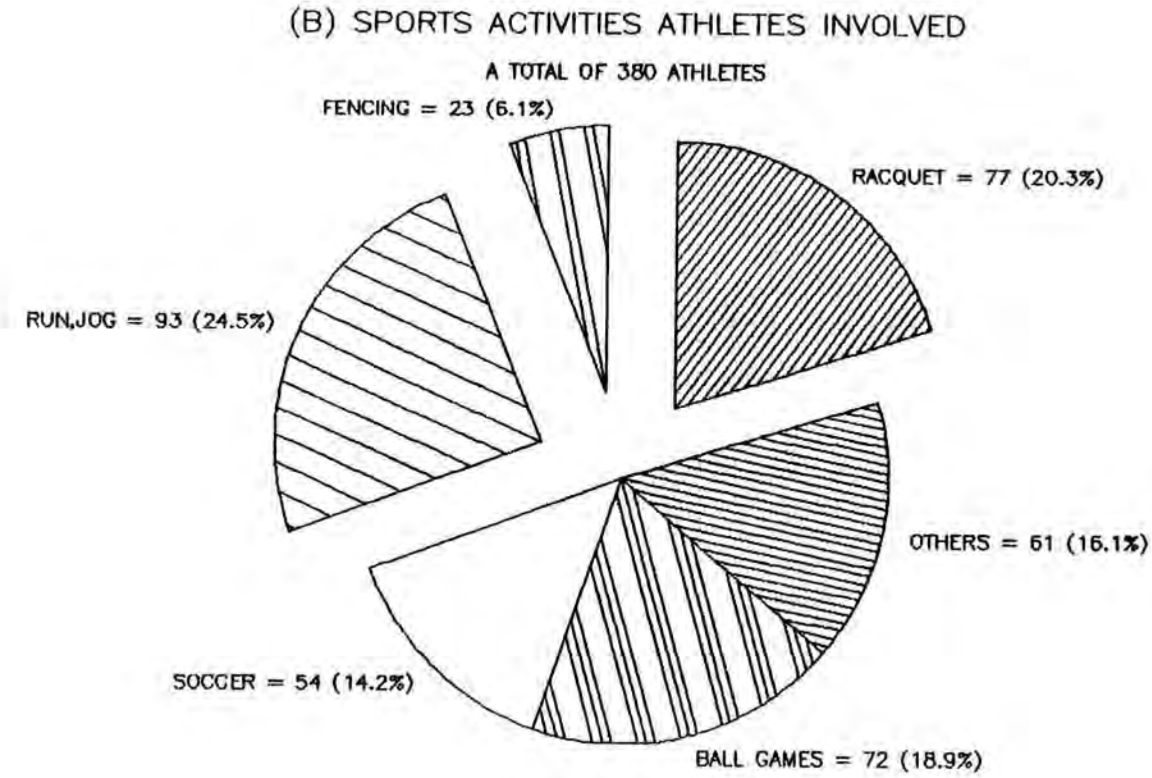


Figure 4.1 Personal Data of Athletes

The athletes were categorized into 3 main groups. There was a fourth group of athletes that could not be classified into either one of the 3 main groups:

1. Hong Kong National Teams' athletes -
athletes in the elite group, representing Hong Kong in various international competitive events.
2. Competitive athletes -
athletes belonging to various school teams, sports teams or clubs members participating sports at competitive level.
3. Recreational athletes -
athletes who were not members of any sports association. They participated in sports for recreational purposes.
4. Others -
athletes who for some reasons required to take part in sports activities or training, for example policeman.

Of the 380 athletes, 64 belonged to the Hong Kong National Teams, 177 were competitive athletes of various sports teams/ clubs, 125 were recreational athletes and 14 belonged to the "others" group. (Figure 4.2)

The frequencies of participation in sports activities per week were presented in figure 4.3. Of the total 380 athletes, 157 (41.3%) of them participated in

A TOTAL OF 380 ATHLETES

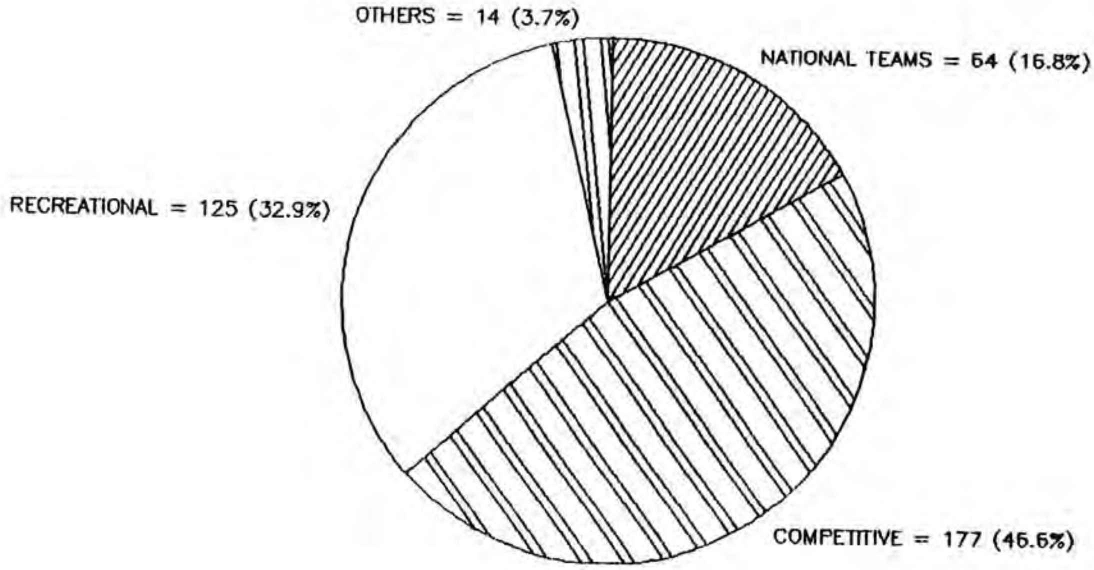


Figure 4.2 **Catagories of Athletes - a total of 380 athletes**

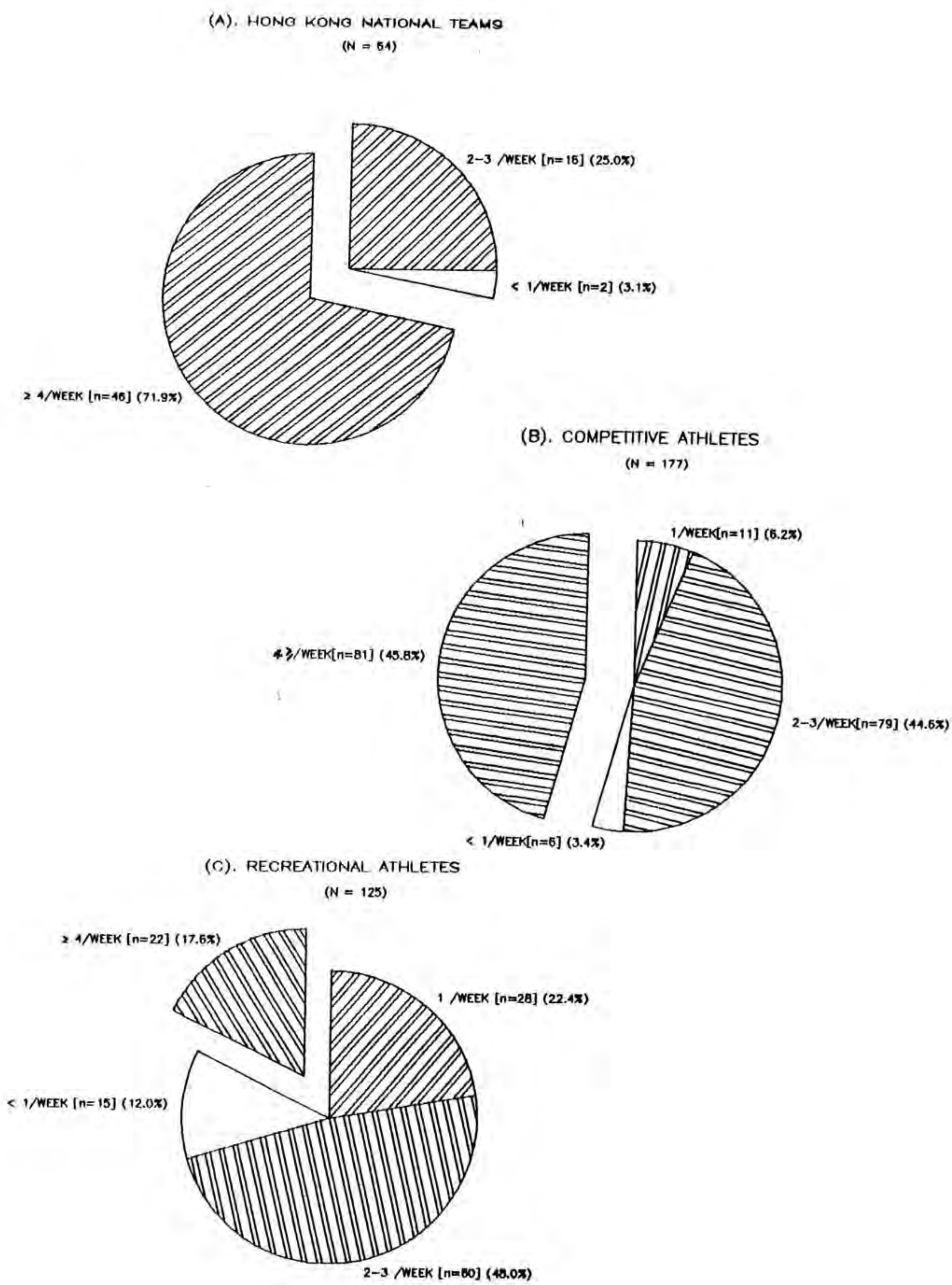
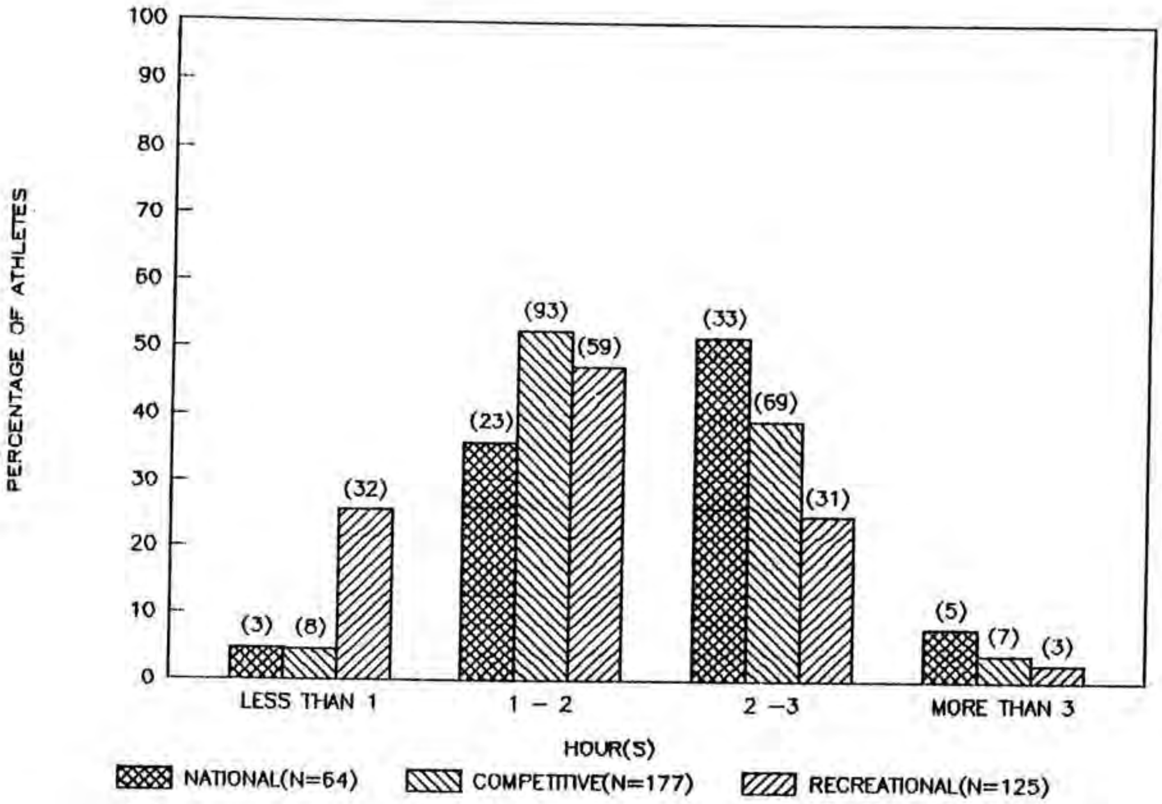


Figure 4.3 **Frequencies of Athletes Participation in Sports Activities Per Week**

sports for 4 times or more per week. Only 26 (6.8%) of them participated in sports for less than once a week. Looking into individual groups of athletes, more than 70% of the Hong Kong National Teams athletes and 45.8% of the competitive athletes participated in sports for 4 or more times per week, while only 17.6% of the recreational athletes involved in sports activities for 4 times or more per week. Statistically, the Hong Kong national athletes participated in sports significantly more frequency than the competitive athletes and recreational athletes; while the competitive athletes also participated in sports activities more frequently than the recreational athletes ($P<0.05$).

The duration or hour(s) athletes spent per session of sports activities was presented in figure 4.4. Most competitive athletes (43.0%) and recreational athletes (27.2%) spent not more than 2 hours per session of sports activities, but 59.4% of the Hong Kong national athletes spent at least 2 hours in each training session. Statistically, the Hong Kong national athletes and the competitive athletes spent a longer time per sports session than the recreational athletes ($P<0.05$).



(N) where N = number of athletes

Figure 4.4 Average Time Spent Per Session of Sports Activities in 3 Groups of Athletes

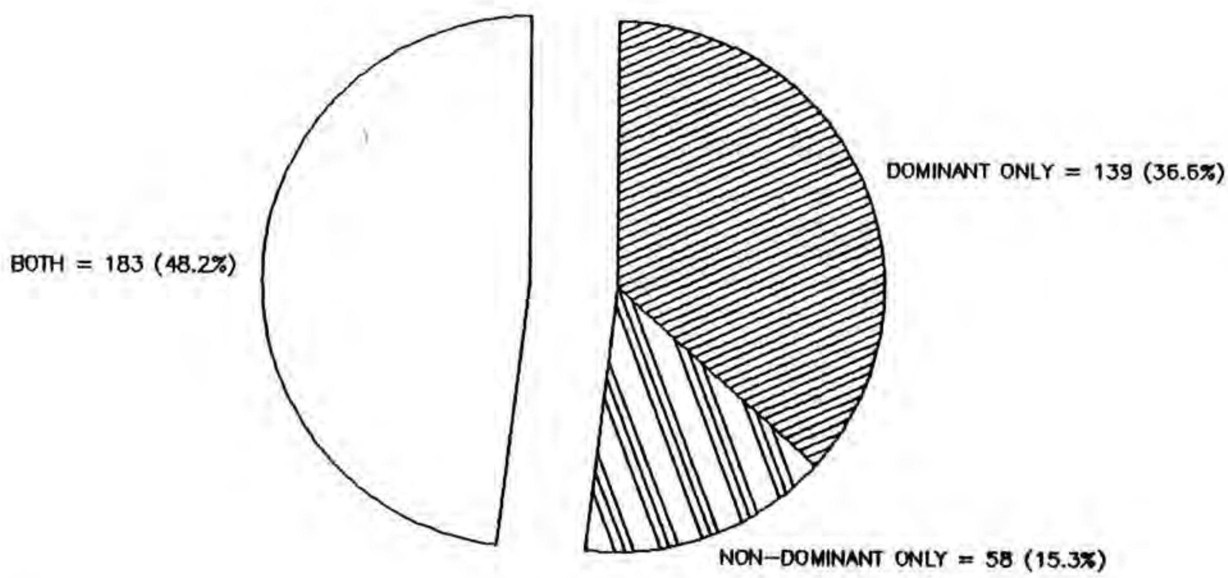


Figure 4.5 Total Number of Ankle Sprains - a Total of 380 Athletes

4.1.2. Athletes' Injury Data

Of the 380 athletes who had previous history of ankle sprain(s), 183 (48.2%) athletes reported that they had bilateral ankle sprains, while 197 athletes had unilateral ankle sprain. Within the 197 athletes with unilateral ankle sprain, 139 (36.5%) athletes reported that only ankle of their dominant leg was injured, and 58 (15.3%) reported that only ankle of their non-dominant leg was injured. Thus, a total of 563 sprained ankles were recorded (Figure 4.5). Injury only to the dominant leg's ankle was 2.39 times higher than injury only to the non-dominant side.

Of these 563 sprained ankles, 149 (26.5%) ankles had sprained once only, while 414 ankles had at least sprained twice. The recurrent rate of ankle sprains for athletes in this studying group was as high as 73.5 percent. Moreover, 124 (22.0%) ankles were reported to have recurrent sprains for 5 times or more. However, when comparing the occurrence rate of ankle sprains among the three groups of athletes, that is, the groups of national, competitive and recreational athletes, there was no significant difference in occurrence rate of sprains among the three groups ($P>0.05$). (Figure 4.6)

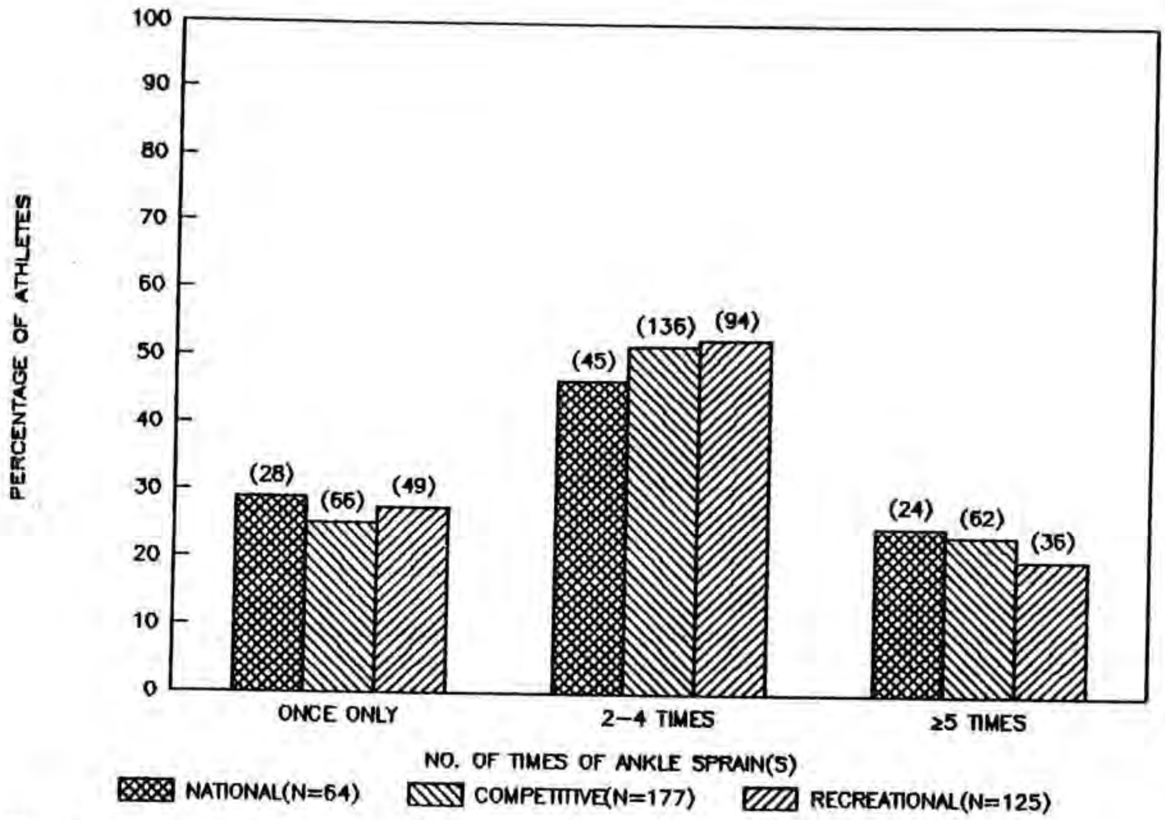


Figure 4.6 Number of Times of Ankle Sprain in 3 Groups of Athletes

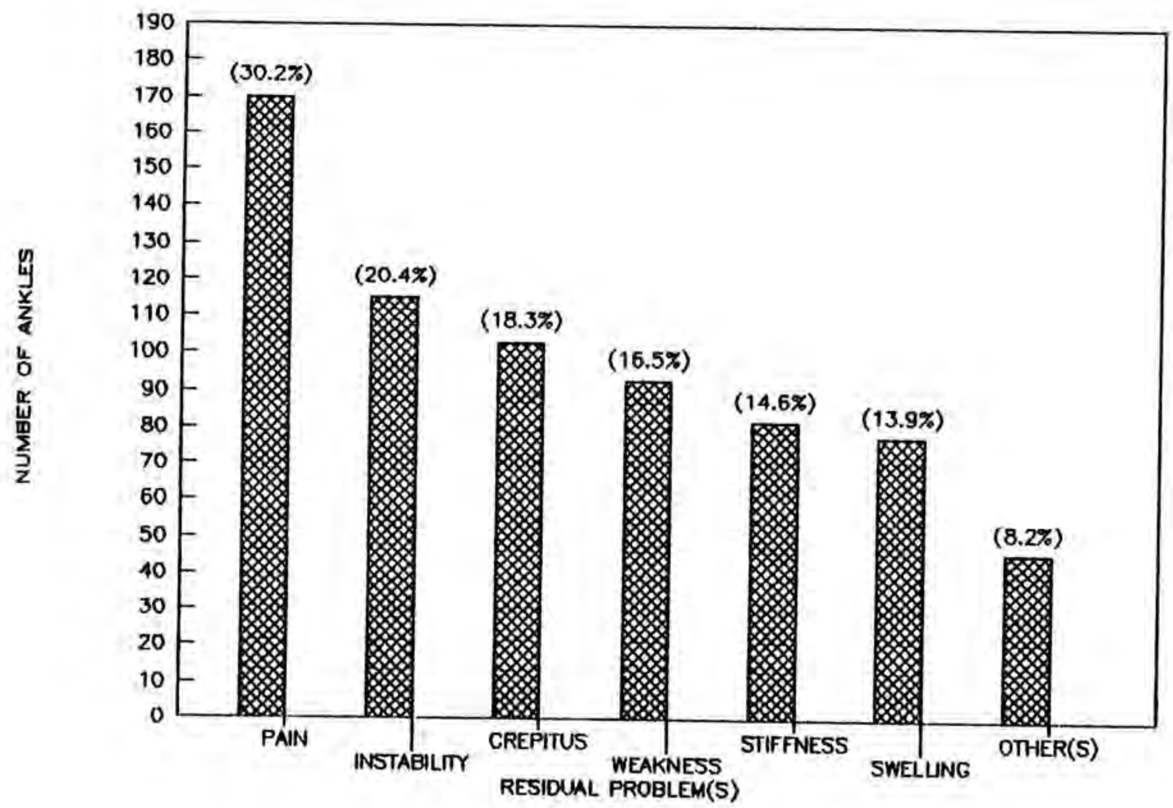


Figure 4.7 Number and Percentages of Various Residual Problems of the Ankles after Sprain(s)

Injury usually occurred at the middle or later part of sports sessions. 19.5% of athletes claimed that their injuries occurred at the start of their sports activities, 42.1% of athletes and 38.4% of athletes said that injuries usually happened in the middle or later part of sports sessions.

4.1.3. Residual Problems in Ankle Sprains

One of the aims in this survey was to study the frequencies in occurrence of various residual signs and symptoms resulting from chronic ankle injuries, therefore, athletes with acute ankle sprain within a three months period were excluded from this survey. Residual symptoms that athletes complained of after ankle sprains were presented in figure 4.7. 30.2% of athletes complained of pain of their injured ankle. It was the major residual problem that athletes had. Followed by sense of instability (20.4% of athletes), crepitus of ankle joints (18.2% of athletes) and weaknesses (16.5% of athletes) in their injured ankles.

The injured or sprained ankles were further divided into 3 sub-groups for analysis of various residual symptoms in relation to the number of times of ankle sprains .

Group A - a total of 149 ankles that had sprained once only;

Group B - a total of 290 ankles that had 2 - 4 times of sprains; and

Group C - a total of 124 ankles that had sprained 5 or more times.

Results showed that there was a trend towards an increase in complaint of residual symptoms with an increase in number of times of ankles sprains (Figure 4.8). For example, only 9.4% of ankles in group A had residual symptom of ankle instability, but 37.9% of ankles in group C had residual symptom of ankle instability. The complaint of ankle instability was 4 times more in group C than that of in group A. For example, there was 10.7% of ankles in group A with symptom of weaknesses, but 25.8% was found of ankles in group C with this symptom.

Statistically, it was found that there was significant difference in the complaint of crepitus, weakness, instability and stiffness among the 3 groups of athletes ($P<0.05$). Athletes who had multiple sprains, their complaints of residual symptoms of crepitus , weakness, instability and stiffness of their injured ankle would increase. However, there were no statistical difference in the complaint of chronic swelling and pain among the three groups of athletes. Comparing data within the three groups of athletes, group C athletes had more complaint of ankle weakness, instability and stiffness than group A and group B athletes ($P<0.05$); while group B athletes had more complaint of ankle instability than group A ($P<0.05$).

There was also a change in the pattern of major complaints with the increase in number of times of ankle sprains. Pain was the major symptom of ankles in group A and B , however, instability became the major complaint of subjects with recurrent ankle sprains for 5 or more times, ie. in group C (Figure 4.8).

Figure 4.9 showed the relationship between the degree of athletic performance being affected with the number of times of ankle sprains. Results showed a trend towards an increase in severity that residual problems affecting athletic performance with an increase in the number of times of ankle sprains. For example, only 3.4% of group A athletes, 7.9% of group B athletes had complained of residual symptoms that often or very often influenced their athletic performance, but 18.5% of group C ankles athletes had complained their level of performance were affected because of the repeated ankle injuries ($P<0.05$).

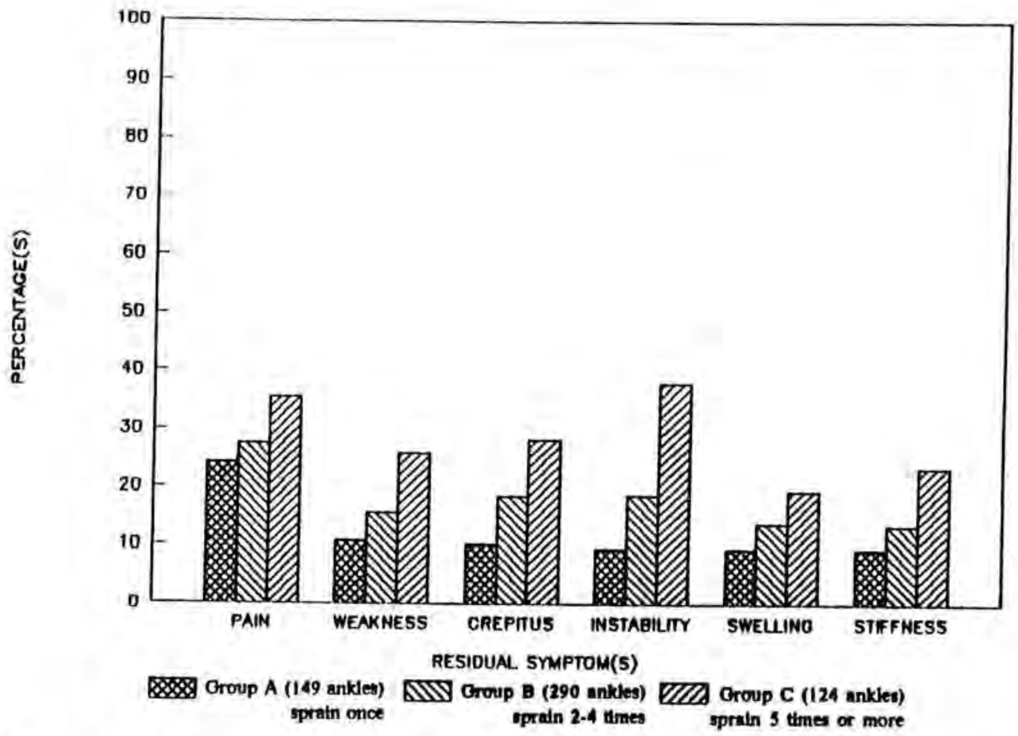


Figure 4.8 Percentage of Various Residual Symptoms in Relation to Times of Ankle Sprains

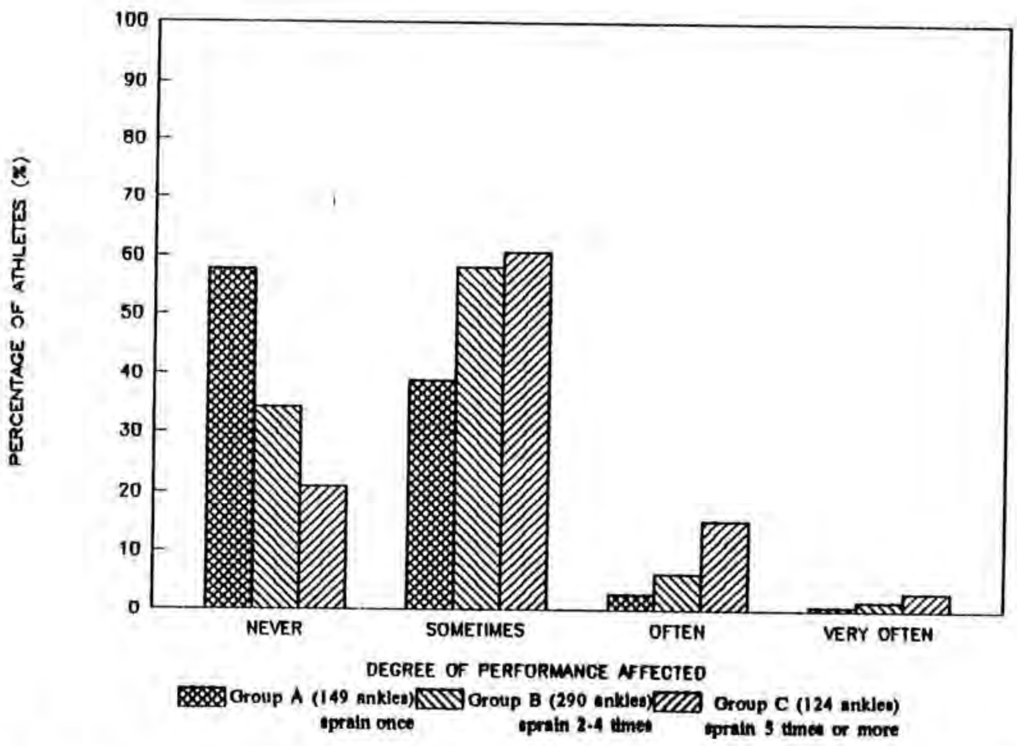


Figure 4.9 Degrees of Performance Affected in Relation to Times of Ankles Sprains

4.2 Isokinetic Evaluation for Normal Uninjured Ankle

4.2.1. Subjects Data

50 subjects (25 males and 25 females), all Hong Kong Chinese, with no history of ankle sprain were tested with the Cybex II+ isokinetic dynamometer. Their mean age was 22.5 ± 4.36 years. Of the 50 subjects, 3 had their left legs as dominant legs and 47 subjects had their right legs as dominant.

4.2.2. Range of Active and Passive Ankle Dorsiflexion

The active and passive range of ankle dorsiflexion was presented in Table 4.1. There was no significant difference in the range of motion of ankle dorsiflexion between the dominant and non-dominant ankles.

Leg / Range	Dominant	Non-Dominant
Active Dorsiflexion	20.9 ± 4.6	20.3 ± 4.0
Passive Dorsiflexion	30.9 ± 5.8	30.2 ± 5.6

Table 4.1 Range of active and passive ankle dorsiflexion for bilateral non-injured ankle

4.2.3. Muscular Parameters Used for Data Analyzing

The following muscular parameters recorded by Cybex Data Reduction Computer were used for data analysis.

(a) Peak torque at 60°/second (in Newton-meter)

(b) Peak torque % body weight (or relative peak torque) at 60°/second (in Newton-meter/Kilogram)

(c) Peak torque at 180°/second (in Newton-meter)

(d) Peak torque % body weight at 180°/second (in Newton-meter/Kilogram)

(e) Peak torque acceleration energy (in Joules)

(f) Total work (in Joules)

(g) Average power (in Watts)

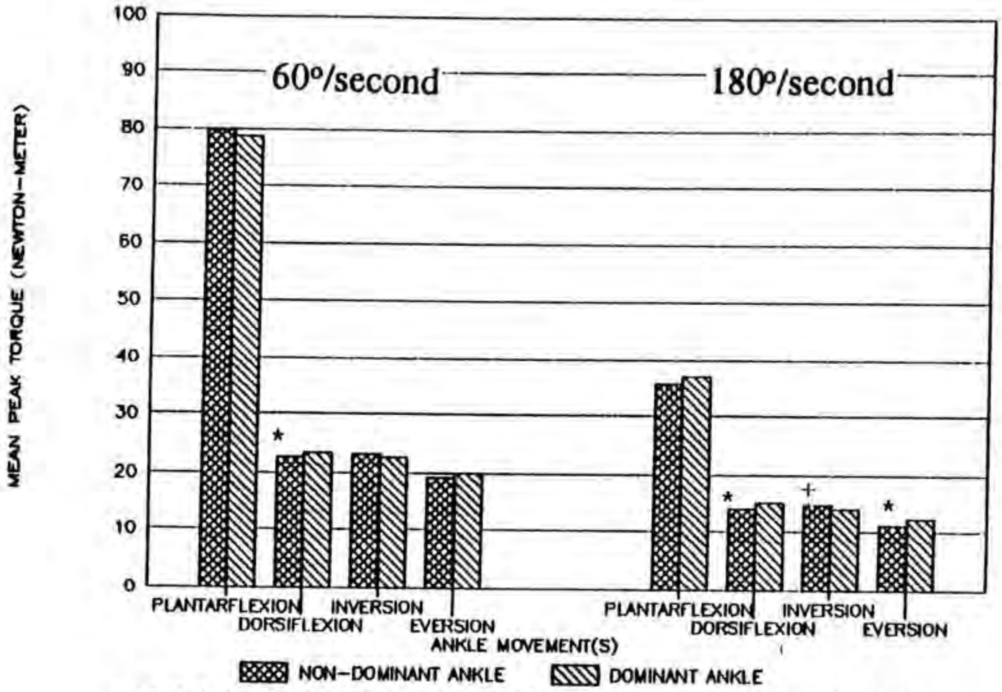
4.2.4. Comparing Muscular Parameters Between Dominant and Non-dominant Ankle of Normal Subjects.

The mean peak torque values for ankle plantarflexor, dorsiflexor, invertor and evertor at 60°/second and 180°/ second for normal subjects, that is, subjects with bilateral non-injured ankles (N=50, where male subjects = 25 and female subjects=25) were presented in figure 4.10.

At test speed of 60° /second, mean peak torque value for ankle dorsiflexor of the dominant ankles was statistically higher than that of the non-dominant ones ($P < 0.05$). There were no statistical differences in mean peak torque values for ankle plantarflexor, invertor and evertor between dominant and non-dominant ankles at test speed of 60°/second.

At test speed of 180°/sec, mean peak torque values of ankle dorsiflexor and evertor of the dominant ankles were statistically higher than those of the non-dominant ankles ($P<0.05$). However, mean peak torque of ankle invertor of the non-dominant ankle was statistically stronger than that of the dominant one ($P<0.05$). (Figure 4.10)

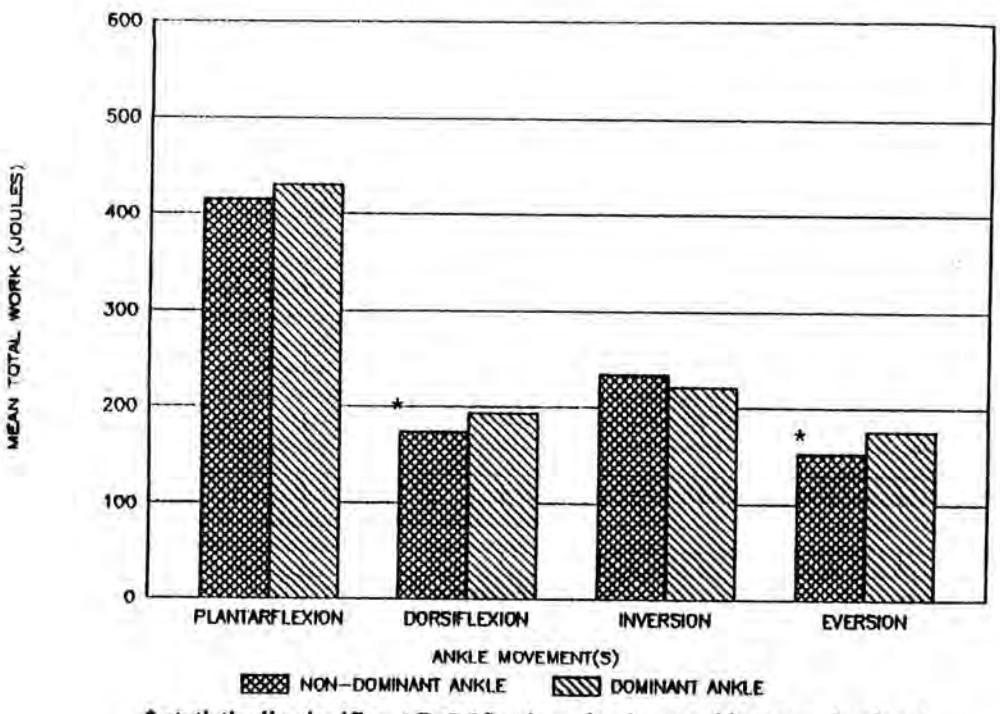
Mean total work and average power of ankle plantarflexors, dorsiflexors, invertors and evertors of normal subjects were presented in Figure 4.11 and 4.12 respectively. Total work in this study was the measurement of work output for 25 repetitions of the tested ankle movements at 180°/second, and average power was the total work output divided by the time used in 25 repetitions of reciprocal muscle contraction. In this study, mean total work, as well as, average power of the dominant ankle dorsiflexors and evertors were statistically higher than those of the non-dominant ankle



* statistically significant P<0.05, where dominant ankle > non-dominant ankle

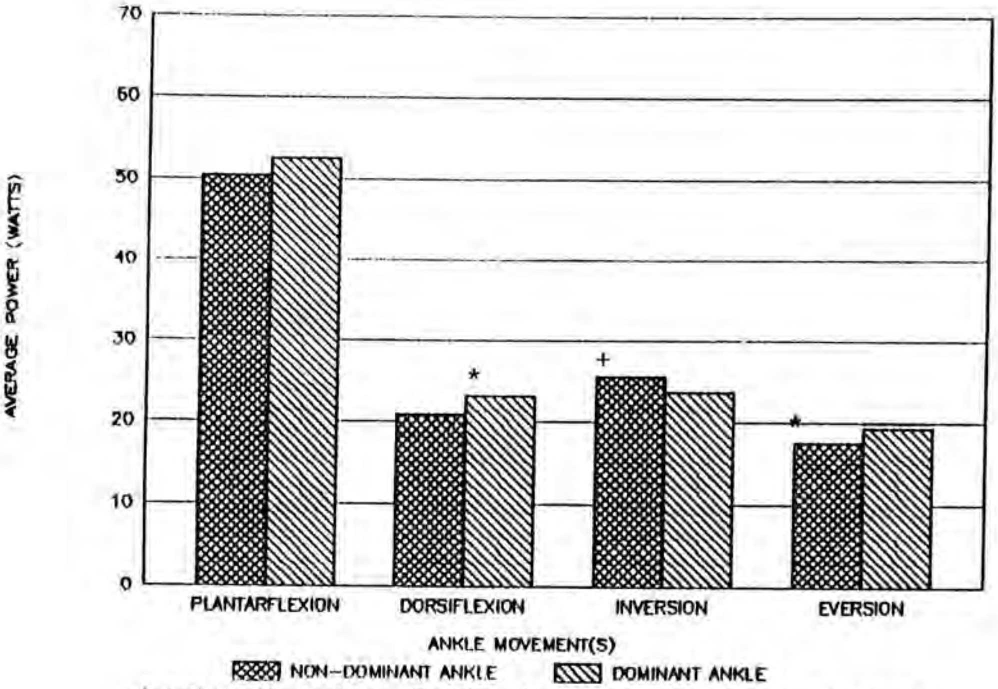
\+ statistically significant P<0.05, where non-dominant ankle > dominant ankle

Figure 4.10 Mean Peak Torques at 60°/second and 180°/second of Muscle Groups in 4 Ankle Movements for Subjects with Non-injured Ankles (normal subjects = 50)



* statistically significant P<0.05, where dominant ankle > non-dominant ankle

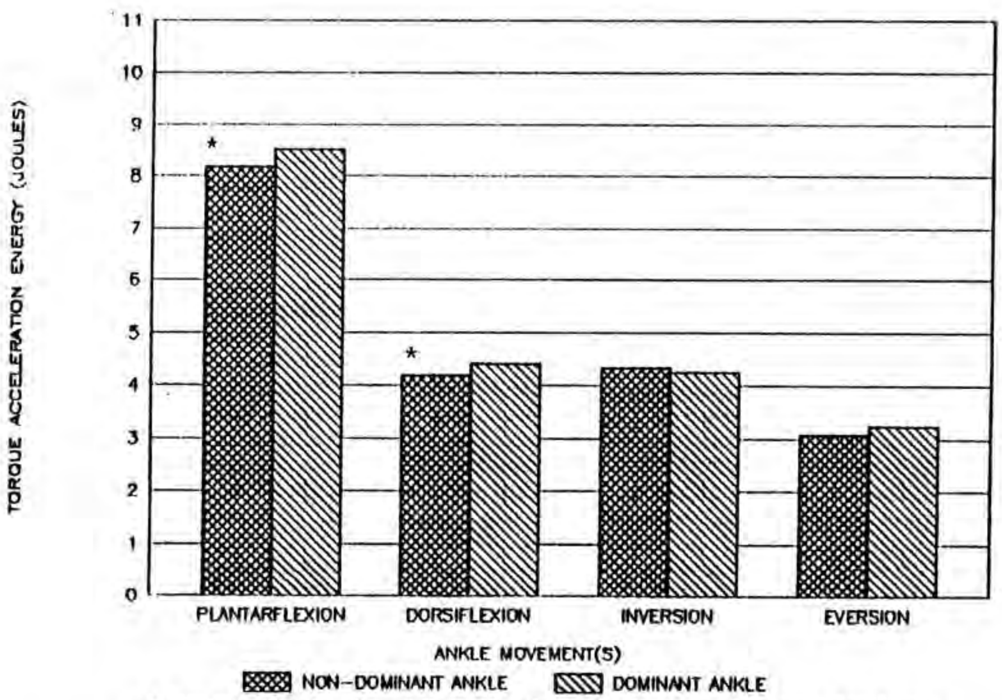
Figure 4.11 Mean Total Work of Muscle Groups in 4 Ankle Movements for Subjects with Non-injured Ankles (normal subject = 50)



* statistically significant P<0.05, where dominant ankle > non-dominant ankle

\+ statistically significant P<0.05, where non-dominant ankle > dominant ankle

Figure 4.12 Average Power of Muscle Groups in 4 Ankle Movements for Subjects with Non-injured Ankles (normal subjects = 50)



* statistically significant P<0.05, where dominant ankle > non-dominant ankle

Figure 4.13 Mean Torque Acceleration Energy of Muscle Groups in 4 Ankle Movements for Subjects with Non-injured Ankles

(P<0.05). But average power of ankle invertor of the non-dominant ankle was statistically higher than that of the dominant one. There were no statistical differences in total work output of ankle plantarflexors and invertor between the dominant and non-dominant ankles, and no statistical difference in average power of ankle plantarflexor between bilateral ankles.

The mean torque acceleration energy (TAE), which is a measurement of the "explosiveness" of muscle contraction, of 4 ankle movements in normal subjects , was presented in figure 4.13 . The TAE of ankle plantarflexors and dorsiflexors of the dominant ankle were statistically higher than that of the non-dominant ankle (p<0.05). However, TAE of ankle invertor and evertor between dominant and non-dominant ankles had shown no statistical difference.

4.2.5. Comparing Muscular Parameters Between Male and Female Normal Subjects

Relative peak torque (peak torque divided by body weight) instead of peak torque values was used for comparing peak muscular force produced between male and female subjects, this parameter could reduce the difference in peak torque measurements due to difference in body weight and size of individual subjects (145). Relative peak torque at 60°/second and 180°/second of 4 ankle movements between male and female subjects were presented in figure 4.14 and 4.15.

For relative peak torque values measured at 60°/second, male subjects consistently had a higher relative peak torque than the females' for all tested ankle movements of both ankles ($P<0.05$), except invertor of the non-dominant ankle, which showed no significant difference between male and female subjects. At test speed of 180°/second, relative peak torque of ankle plantarflexor, dorsiflexor and evertor in male and female subjects were statistically significantly different. The male was consistently stronger than the female ($P<0.05$), except ankle invertor of both ankles, where no statistical difference in relative peak torque between male and female subjects were measured.

Total work output of the 4 ankle muscle groups between male and female normal subjects were shown in figure 4.16 . Plantarflexor, evertor of both dominant and non-dominant ankles and dorsiflexor of the dominant ankle in male subjects were statistically higher in total

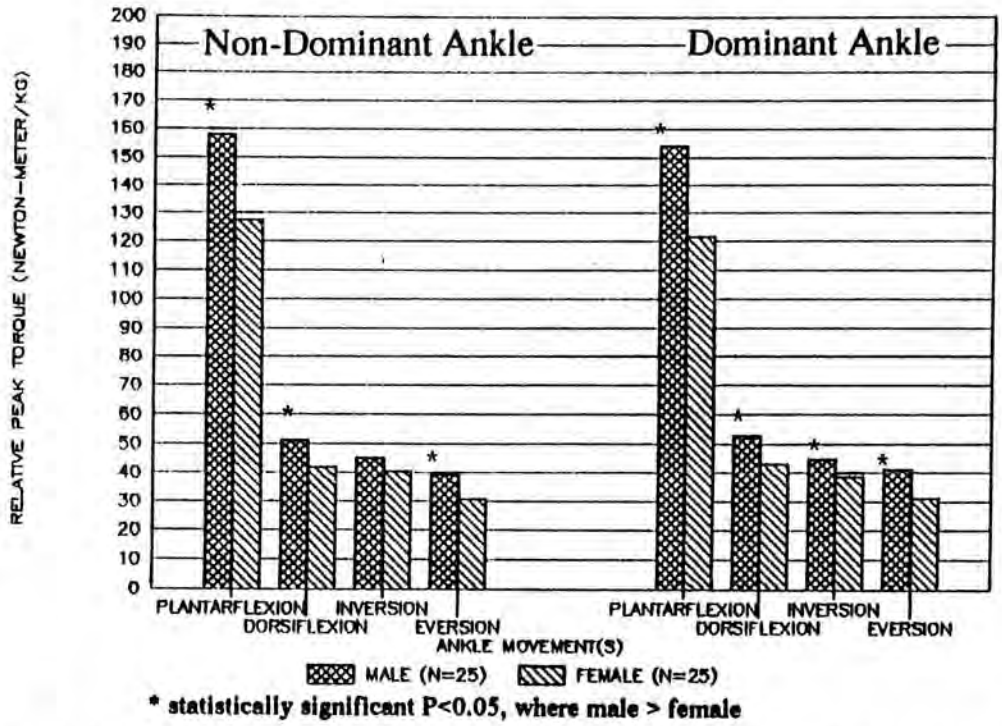


Figure 4.14 Relative Peak Torque at 60°/second of Muscle Groups in 4 Ankle Movements for Male and Female Subjects

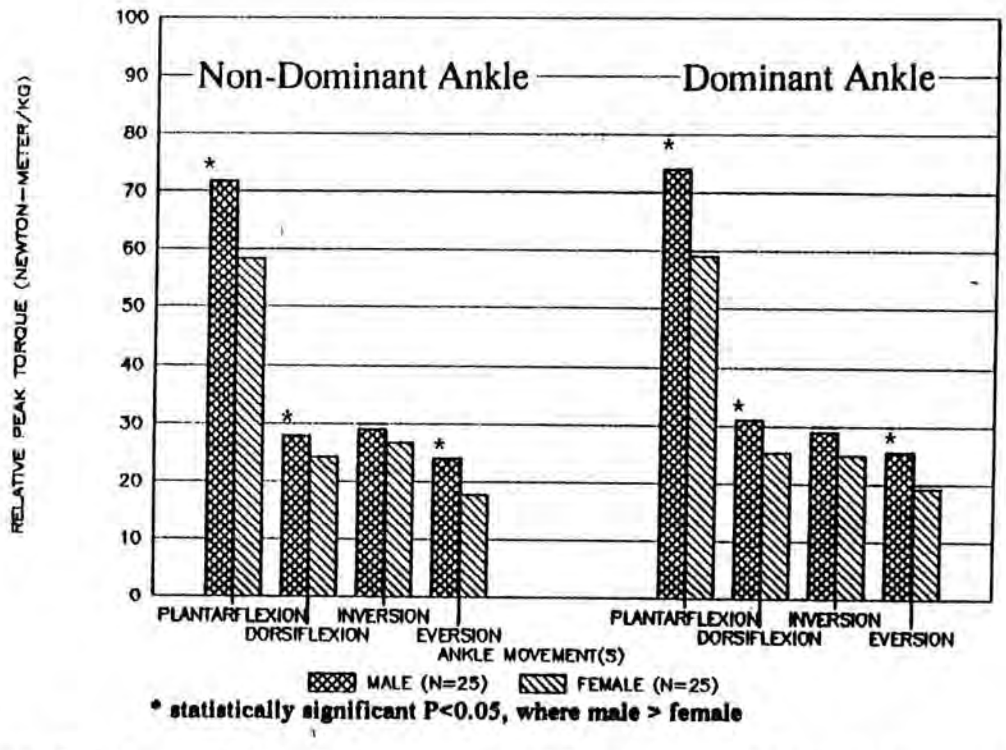


Figure 4.15 Relative Peak Torque at 180°/second of Muscle Groups in 4 Ankle Movements for Male and Female Subjects

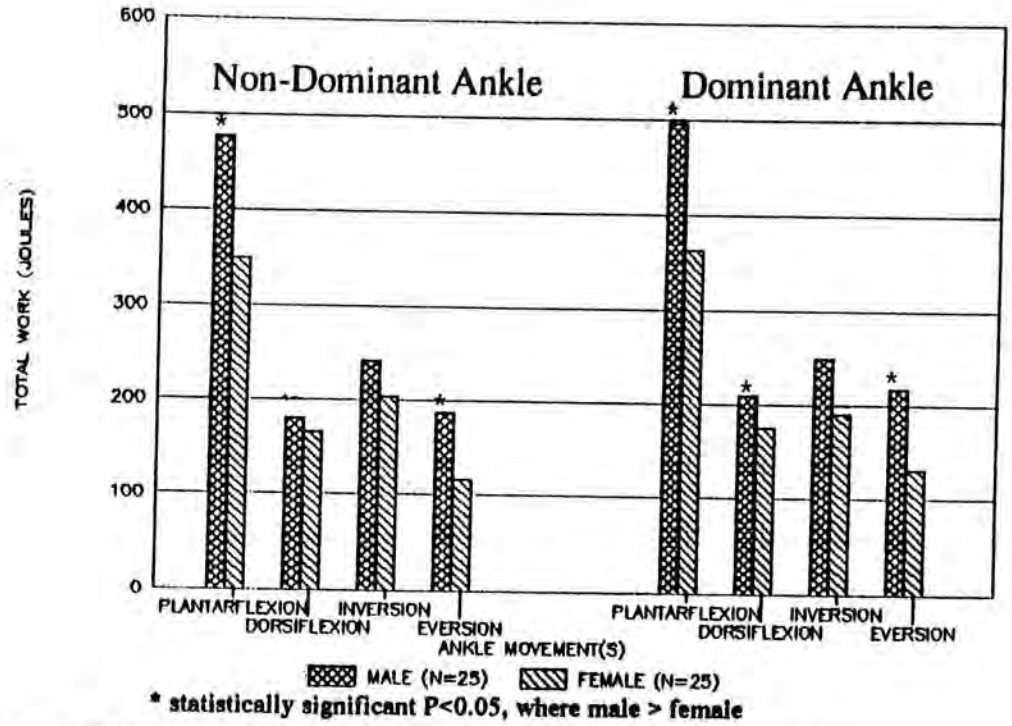


Figure 4.16 Total Work of Muscle Groups in 4 Ankle Movements for Male and Female Subjects

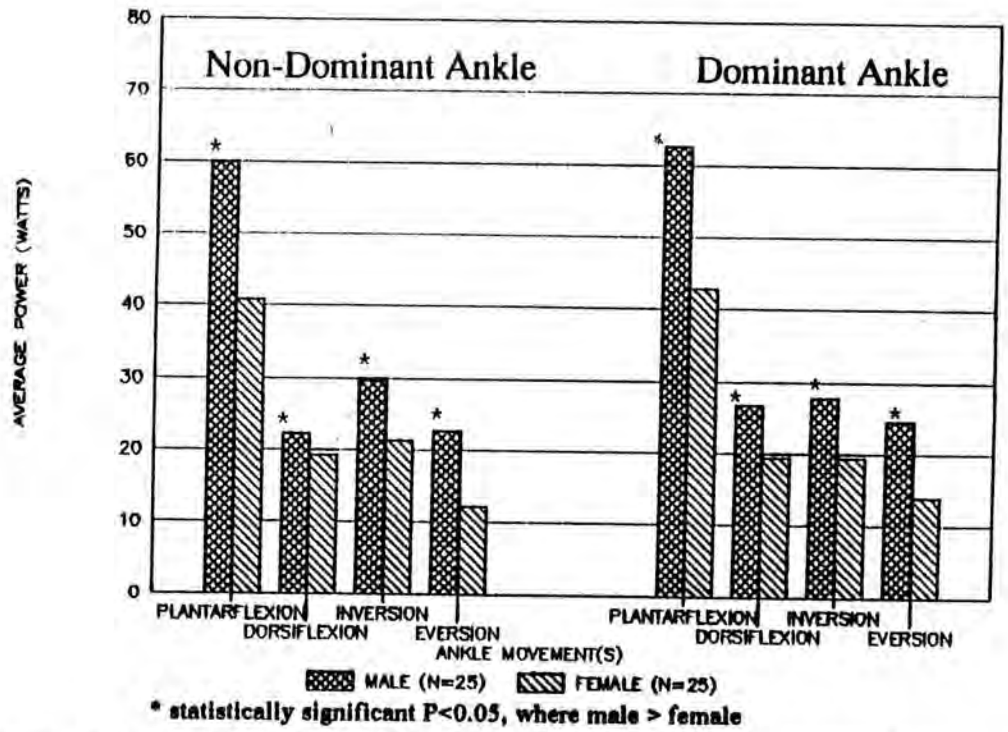


Figure 4.17 Average Power of Muscle Groups in 4 Ankle Movements for Male and Female Subjects

work than that in female subjects ($P<0.05$). For the measurement of average power of the 4 ankle movements, average power for male subjects was consistently higher than that of female for both dominant and non-dominant ankles ($P<0.05$), except plantarflexor of the dominant ankle where no statistical difference between male and female subjects was found. (Figure 4.17)

Mean torque acceleration of the 4 ankle muscle groups for both male and female subjects were presented in figure 4.18. Torque acceleration energy of male subjects were consistently higher than that of female subjects at all the tested movements ($P<0.05$).

4.2.6. Torque Ratio and Work Ratio

Mean peak torque ratio and mean total work ratio of ankle dorsiflexion/plantarflexion (DF/PF), and eversion/inversion (EV/INV) was presented in table 4.2 and 4.3. These were the ratios of peak torque or total work of the agonistic and antagonistic muscle groups.

Mean peak torque ratio for ankle dorsiflexion / plantarflexion was around 33% and 41% at test speeds of 60°/second and 180°/second respectively. Mean peak torque

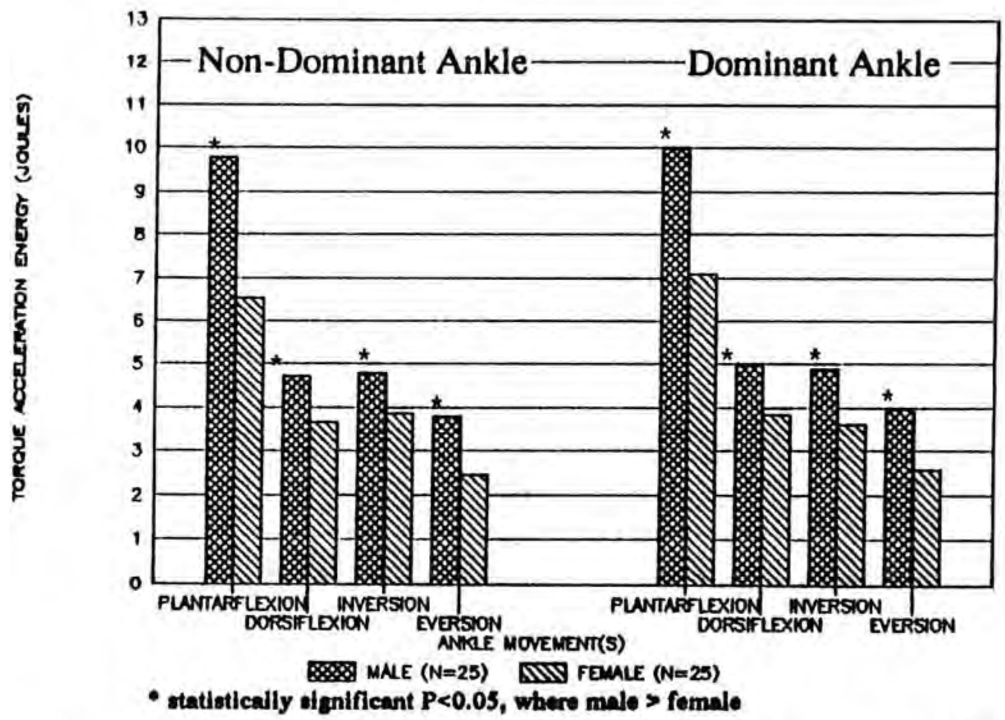


Figure 4.18 Torque Acceleration Energy of Muscle Groups in 4 Ankle Movements for Male and Female Subjects

Relative Torque Ratio	Speed Test (∘/sec)	Overall		Male		Female	
		Non-Dom (%)	Dom (%)	Non-Dom (%)	Dom (%)	Non-Dom (%)	Dom (%)
DF/PF (x 100%)	60 180	32.6 40.5	34.9 42.4	32.4 39.7	34.5 41.9	32.8 41.4	35.4 42.9
Ev/Inv (x 100%)	60 180	81.6 74.9	86.8 84.5	86.5 82.8	91.3 91.1	76.3 66.4	81.3 77.1

Non-Dom = Non-dominant ankle   Dom = Dominant ankle

Table 4.2 Mean relative peak torque ratio of ankle dorsi flexion/plantarflexion (DF/PF), and eversion/inversion (Ev/Inv) of the ankle. (overall subjects N=50, male N=25, female N=25)

	Work Ratio					
	Overall (N=50)		Male (N=25)		Female (N=25)	
	Non-Dom	Dom	Non-Dom	Dom	Non-Dom	Dom
DF/PF	41.9	44.9	37.8	42.4	47.6	48.4
Ev/Inv	68.4	79.4	77.4	87.0	57.6	69.6

Non-Dom = Non-dominant ankle   Dom = Dominant ankle

Table 4.3 Work ratio of ankle dorsiflexion/plantarflexion, and eversion/inversion of ankle (overall subjects N = 50, male N = 25, female N = 25) ratio for ankle eversion / inversion was around 84% and 80% at test speeds of 60°/second and 180°/second. The ratio of ankle DF/PF was similar for both male and female subjects. However, the ratio of ankle EV/INV was higher in the male subjects than the female subjects at the two testing speeds. (Table 4.2)

Mean work ratio of ankle DF/PF and EV/INV were around 43% and 74% respectively at test speed of 180°/second. The work ratio for ankle DF/PF was higher in female subjects, but work ratio for ankle EV/INV was higher in male subjects. Furthermore, these ratios were also higher for the dominant ankles. (Table 4.3)

4.3. Evaluation for Ankles with Inversion Sprain

4.3.1. Initial Evaluation

4.3.1.1. Subjects Data

31 subjects, 25 male and 6 females, all Hong Kong Chinese, with history of unilateral recurrent ankle inversion sprains had participated in this part of the study. Their mean age was 25.3 ± 5.5 years. Of these 31 subjects, 21 had injured their dominant ankles, while 10 had injured their non-dominant ankles.

These subjects involved in various types of sports activities. Sports activities athletes involved in were listed :-

3 Fencing	2 Badminton	1 Soccer
9 Track events	7 Basketball	1 Squash
6 Orienteering	1 Long jump	1 Weight Training

Detailed injury histories and management methods for their ankle sprains were recorded. Of these 31 subjects, 8 of them had seen bone-setter, 9 with self treatment with either ice or ointment. 2 had consulted general practitioner, and 12 had seen doctors and referred for physical therapy. However, only half of them said that exercise programme were given for their sprained ankle, the other 6 claimed they only had electrotherapeutics modalities treatment and no exercise programme had been taught or prescribed.

4.3.1.2 Anterior Draw Sign

Anterior draw test was done by a medical doctor manually who had not been informed which ankle the athletes had injured. 12 ankles had demonstrated positive anterior draw sign in their injured ankles, while 19 had shown no sign of anterior subluxation in their injured ankles by manual testing.

4.3.1.3 Range of Motion

When comparing the ranges of movmement of active and passive ankle dorsiflexion, the injured ankle had statistically decreased in both active and passive ranges than that of the non-injured side ($P<0.05$) (Table 4.4).

Leg / Range	Non-Injured	Injured
Active Dorsiflexion	21.4 ± 4.8	19.1 ± 4.5
Passive Dorsiflexion	35.0 ± 6.1	32.5 ± 6.6

Table 4.4 Range of active and passive ankle dorsiflexion for injured and non-injured ankle

4.3.1.4 Ankle Functional Rating Scale

The mean score for ankle function rating scale in the initial evaluation was 82.3 ± 8.6 points out of 100 points. None of the 31 subjects got 100 points in their initial evaluation by this scaling system.

4.3.1.5 Isokinetic Evaluation

(a) Comparing muscular parameters for subjects with unilateral recurrent sprains to the dominant ankles.

A total of 21 subjects with unilateral recurrent sprains to the dominant ankles were tested in the initial isokinetic ankle evaluation.

Mean peak torques of ankle dorsiflexor, plantarflexor, invertor and evertor of the injured (dominant) ankles were generally lower than that of the non-injured (non-dominant) side at both 60°/second and 180°/second test speeds. At 60°/ second, peak torques of ankle plantarflexor and evertor of the injured ankles were significantly lower than the non-injured ones ($P<0.05$). At 180°/second, dorsiflexor and invertor of the injured ankles had a significantly lower peak torque than the non-injured (non-dominant) ones ($P<0.05$). The mean peak torque values at 60°/second and 180°/second were presented in Figure 4.19 and 4.20 respectively.

There was no statistical difference in total work output between the injured and non-injured ankles (Figure 4.21). However, average power of the injured ankle plantarflexor and invertor were significantly lower than the non-injured leg ($p<0.05$) (Figure 4.22).

Analyzing torque acceleration energy (TAE) of the 4 ankle muscle groups, TAE of ankle plantarflexor, invertor and evertor of the injured ankles had decreased significantly when compared with the non-injured sides ($P<0.05$). (Figure 4.23)

(b) Comparing muscular parameters for subjects with unilateral recurrent sprains to their non-dominant ankles

A total of 10 subjects with unilateral recurrent sprains to their non-dominant ankles were tested in the initial isokinetic evaluation.

In general, the injured (non-dominant) ankle had lower peak torque values than the non-injured (dominant)

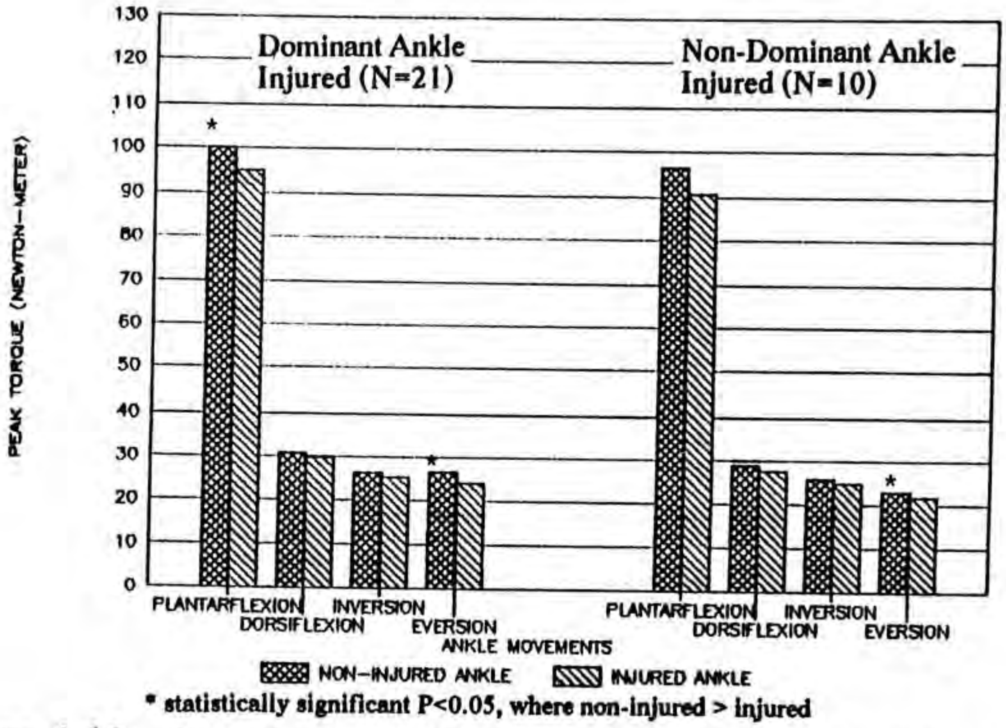


Figure 4.19 Peak Torque at 60°/second of Muscle Groups in 4 Ankle Movements for Subjects with Unilateral Recurrent Ankle Sprain

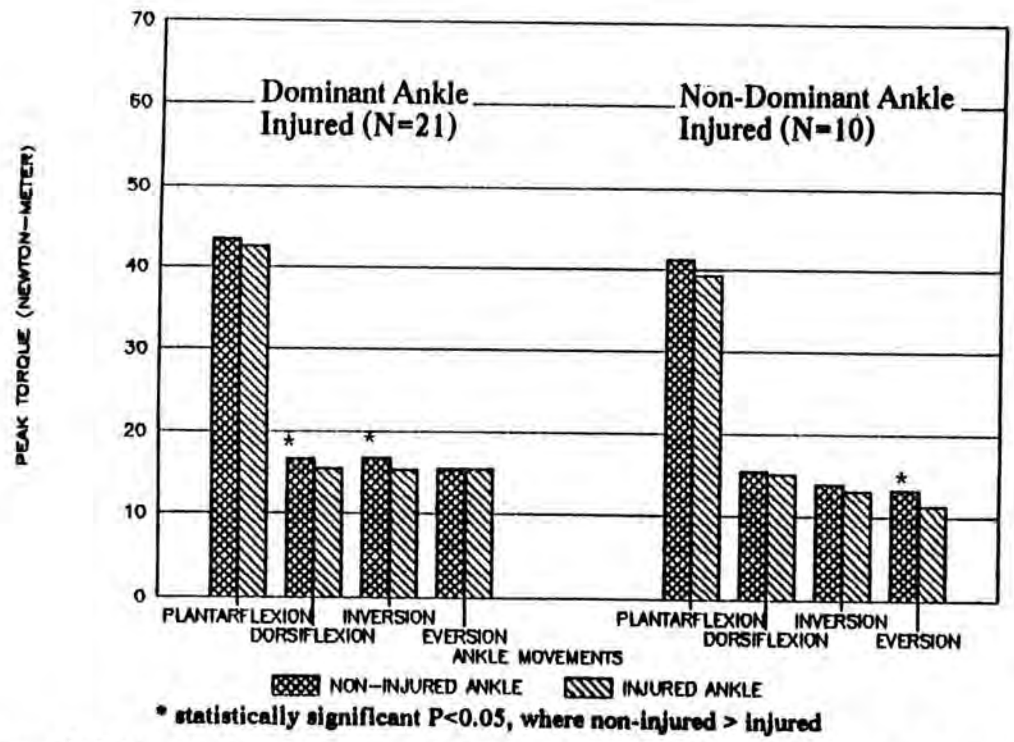


Figure 4.20 Peak Torque at 180°/second of Muscle Groups in 4 Ankle Movements for Subjects with Unilateral Recurrent Ankle Sprain

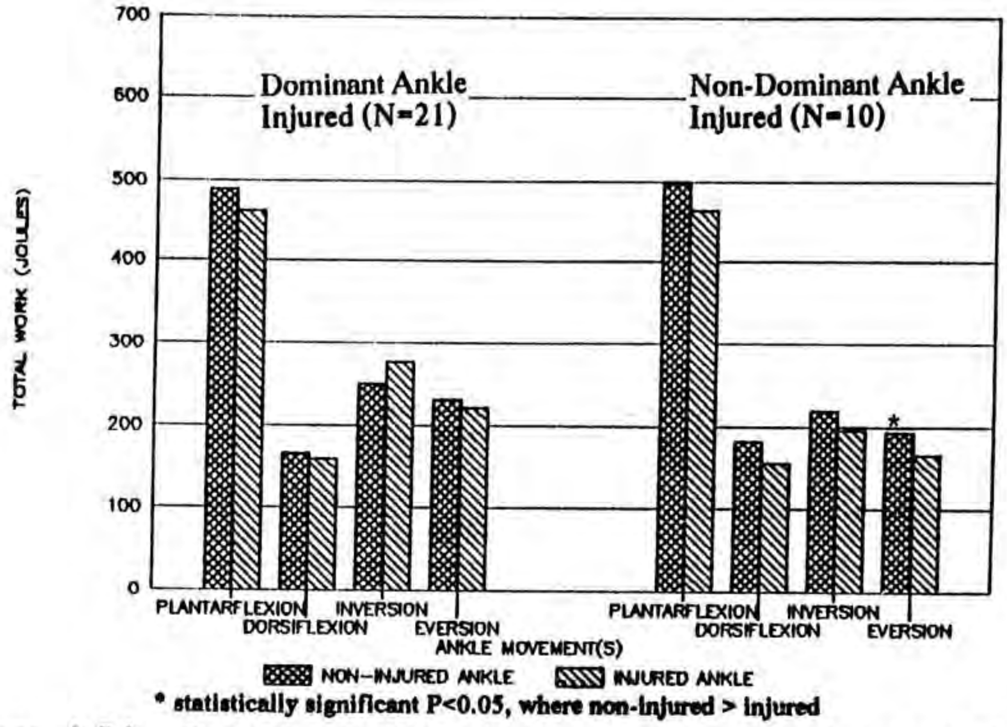


Figure 4.21 Total Work of Muscle Groups in 4 Ankle Movements for Subjects with Unilateral Recurrent Ankle Sprain

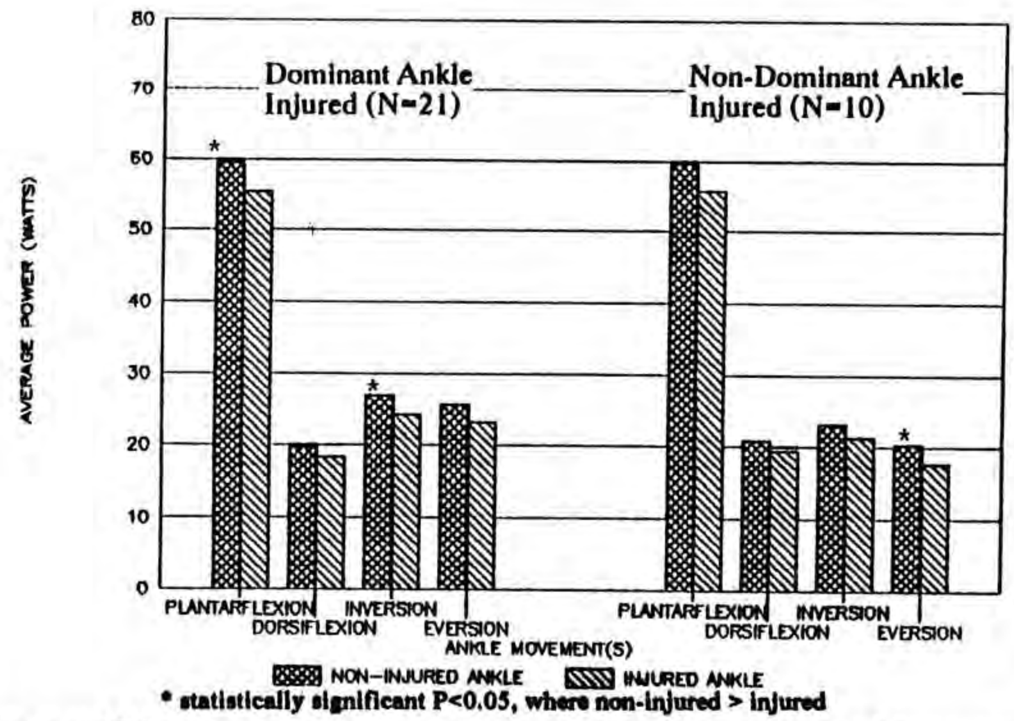


Figure 4.22 Average Power of Muscle Groups in 4 Ankle Movements for Subjects with Unilateral Recurrent Ankle Sprain

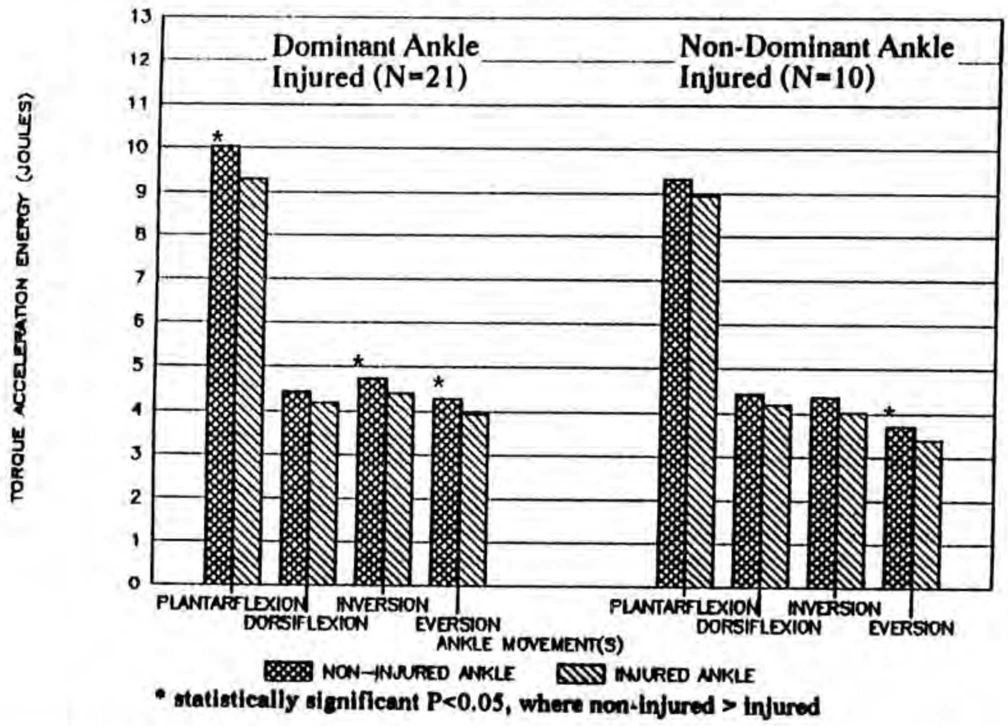


Figure 4.23 Torque Acceleration of Muscle Groups in 4 Ankle Movements for Subjects with Unilateral Ankle Recurrent Sprain

ankle at test speeds of 60°/second and 180°/second respectively. However, only peak torque of ankle evertors of the injured (non-dominant) ankles was statistical significantly lower than the non-injured ones ($P<0.05$) at both test speeds. (Figure 4.19 and 4.20)

Total work and average power of ankle evertor of the injured (non-dominant) ankles were significantly lower than that of the non-injured ones ($P<0.05$). Generally, total work and average power in the injured ankles were lower than that of the non-injured ones, but there were no statistical difference shown (Figure 4.21 and 4.22). Torque acceleration energy of ankle evertor in the injured ankles was also statistically lower ($P<0.05$) (Figure 4.23).

(d) Comparing muscular parameters of normal subjects (with bilateral non-injured ankles) and subjects with unilateral recurrent ankle sprains.

Table 4.5 summarized the results of isokinetic testing of various muscular parameters between dominant and non-dominant ankles, and between injured and non-injured ankles.

		Normal Ankle (N=50)	Injured Dominant Ankle (N=21)	Injured Non-Dominant Ankle (N=10)
Peak Torque at 60°/sec.	PF	NS	* ND>Di	NS
	DF	* D>ND	NS	NS
	Inv	NS	NS	NS
	Ev	NS	* ND>Di	* D>NDi
Peak Torque at 180°/sec.	PF	NS	NS	NS
	DF	* D>ND	* ND>Di	NS
	Inv	* ND>D	* ND>Di	NS
	Ev	* D>ND	NS	* D>NDi
Total Work	PF	NS	NS	NS
	DF	* D>ND	NS	NS
	Inv	NS	NS	NS
	Ev	* D>ND	NS	* D>NDi
Average Power	PF	NS	* ND>Di	NS
	DF	* D>ND	NS	NS
	Inv	* ND>D	* ND>Di	NS
	Ev	* D>ND	NS	* D>NDi
Torque Acceleration Energy	PF	* D>ND	* ND>Di	NS
	DF	* D>ND	NS	NS
	Inv	NS	* ND>Di	NS
	Ev	NS	* ND>Di	* D>NDi

PF = plantarflexion   Inv = inversion   D = dominant ankle
DF = dorsiflexion   Ev = eversion   ND = non-dominant ankle
i = injured

* statistical significant $P<0.05$

Table 4.5 Summary of isokinetic testing results - bilateral comparison of various muscular parameters of the ankles in 3 groups of subjects.

(i) Peak torque at 60°/second

In normal subjects, there was no significant difference in ankle plantarflexor strength between dominant and non-dominant ankle. However, for subjects with dominant ankle injured, plantarflexor of the injured dominant ankles decrease significantly in peak torque when compared with the non-dominant ankles.

In normal subjects, peak torque of dorsiflexor of the dominant ankles was significantly higher than that of the non-dominant ones ($P<0.05$). In the injury group, dorsiflexor peak torques of the injured (dominant) and non-dominant ankle were similar.

Peak torque of ankle evertor in normal subjects had no significant difference between dominant and non-dominant ankles. However, in subjects with dominant ankle sprain, peak torque of evertor muscles of the injured (dominant) ankle was statistically lower than that of the non-injured (non-dominant) ankle. On the other hand, subjects with non-dominant ankle sprain, peak torque of evertor muscle of the injured (non-dominant) ankle was significantly lower than that of the non-injured dominant leg.

(ii) Peak torque at 180°/second

In normal subjects, peak torque of ankle dorsiflexors of the dominant ankles was higher than that of the non-dominant ones ($P<0.05$). For subjects with dominant ankle injured, their non-dominant ankle dorsiflexors was significantly stronger than that of the dominant ones ($P<0.05$).

In normal subjects and subjects with dominant ankles injured, peak torque of invertor was statistically higher in non-dominant ankles than dominant ankles. For subjects with non-dominant ankle injured, peak torques of the invertor were similar for both ankles. No statistical difference was found.

In normal subjects, peak torque of evertor of the dominant ankles was significantly higher than that of the non-dominant ones ($P<0.05$). For subjects with dominant ankle injured, no difference in peak torques was found between the injured (dominant) and non-injured (non-dominant) ankles. For subjects with non-dominant ankle injured, evertor of the non-injured (dominant) ankles was significantly stronger than injured (non-dominant) ankle.

(iii) Total work

In normal subjects, dorsiflexor of dominant ankles had a significantly higher total work output than the non-dominant ones ($P<0.05$). However, for subjects with injured ankles, total work of ankle dorsiflexor was similar between ankles.

In normal subjects, total work output for evertors of the dominant ankles was significantly higher ($P<0.05$). For subjects with injured dominant ankles, ankle evertors of the injured (dominant) ankle had similar total work output comparing with the non-dominant side. For subjects with injured (non-dominant) ankles, total work of the injured ankles was significantly lower when compared to that of the non-injured side.

(iv) Average power

In normal subjects and subjects with non-dominant ankle injured, no significant difference in average power of ankle plantarflexor was found between the two ankles. However, for subjects with dominant ankle injured, average power of ankle plantarflexor of the injured (dominant) ankles was significantly lower.

In normal subjects, dorsiflexors of the dominant ankles had a higher average power than that of the non-dominant ankles. However, for subjects with injured dominant ankles no difference in average power of ankle dorsiflexors were shown between both legs.

For normal subjects, average power of ankle evertors was significantly higher in the dominant ankle ($P<0.05$). Subjects with dominant ankle injured also decreased in average power in the dominant ankle ($p<0.05$). Subjects with non-dominant ankle injured, the average power did not show any difference statistically when both ankles were compared.

In normal subjects, the evertor muscle of the dominant ankle had a statistically higher average power than that of the non-dominant ankles ($P<0.05$). For subjects with injured (dominant) ankle, ankle evertor did not show a higher average power in the dominant ankle, while for subjects with their non-dominant ankle injured, the average power of the evertor of the dominant ankles was higher than that of the non-dominant ones ($P<0.05$).

(v) Peak torque acceleration energy (TAE),

In normal subjects, ankle plantarflexor of the dominant ankles had a higher TAE than that of the non-dominant ones ($P<0.05$). When subjects injured their dominant ankles, the non-dominant ankle plantarflexor instead, had a significantly higher TAE than the dominant (injured) ones.

In normal subjects, TAE of ankle dorsiflexor was higher in the dominant ankles ($P<0.05$), for subjects with injured ankles, there was no statistical difference in TAE measured between two ankles. The TAE of ankle invertor for normal subjects and subjects with non-dominant ankle injured showed no statistical difference. However, for subjects with dominant ankle injured, the TAE of ankle invertor was significantly lower in the dominant ankles. In normal subjects, TAE of evertor muscles had no statistical difference between both ankles. However, for subjects with dominant ankle injured, the TAE of ankle evertor was lower in the injured (dominant) ankles, and for subjects with non-dominant ankle injured, TAE of ankle evertor was statistically lower in the injured non-dominant ankles.

4.3.2 Second Evaluation

4.3.2.1 Subjects Data

31 subjects, with unilateral recurrent ankle sprains were randomly divided into 2 groups. The first group consisted of 16 subjects. They were the exercise or training group. An isokinetic exercise programme was prescribed for strengthening the ankle plantarflexors, dorsiflexors, invertors and evertors. The second group was the non-exercise group or the control group which consisted of 15 subjects.

However, in the second evaluation, 5 subjects were "lost", leaving 26 subjects available for the re-testing. Of the 5 "lost" subjects, two were from the exercise group. They were excluded from the testing because one did not attend the regular exercise training program, and the other had tendinitis of the ankle during the training period. For the control group, two subjects in the control group went aboard and one had lost contact and did not return for the re-test. Therefore, a total of 14 subjects (12 male and 2 female) in the exercise group and 12 subjects (10 male and 2 female) in the control group had completed the second evaluation.

4.3.2.2 Comparing the Initial and Second Ankle Functional Rating Scale

In order to have comparable data for evaluating the effect of exercise training upon functional performance of ankles with recurrent ankle sprains, data of 26 subjects, who had completed the ankle functional rating scale and isokinetic assessments, were utilized for the study of isokinetic training effect on ankle sprain.

The mean ankle functional rating scores for the exercise group and the non-exercise group in the initial testing were 80.71 ± 10.19 points and 83.75 ± 6.21 points out of 100 points respectively. The functional rating scores in the second evaluation for the training group with isokinetic exercise training programme was 90.29 ± 7.07 points. The mean score in the second reassessment was significantly higher than that of the initial score in the exercise group ($P<0.05$). In the non-exercise group, the mean score for the second ankle functional rating was 84.33 ± 5.40 points and no significant change was observed in the reassessment for these athletes (Table 4.6).

Functional Score	Exercise *	Non-exercise
Initial Test	80.71 ± 10.19	83.75 ± 6.21
Re-test	90.29 ± 7.07	84.33 ± 5.40

* Statistically significant $P<0.05$, where exercise > non-exercise

Table 4.6 Ankle Functional Rating Scale Scores for Initial and Re-test for subjects in Exercise and Non-exercise Groups

4.3.2.3 Comparing Initial and Second Evaluation for Isokinetic Parameters of the Ankle

It was obvious in this study that all isokinetic parameters of all 4 ankle muscle groups had increased significantly in the exercise group. There was no statistical difference in all isokinetic parameters for the non-exercise group.

(i) At 60°/second

There was insignificant changes in mean peak torques for ankle plantarflexors, dorsiflexors, invertors and evertors in the non-exercise group. In the exercise group, the mean increase in peak torque for ankle plantarflexion, dorsiflexion, inversion were ranging from 13-15%, and there was an 44.6% increment in peak torque for ankle evertor (Figure 4.24.)

(ii) At 180°/second

There was no statistical difference in peak torque for the initial and second isokinetic evaluation for the non-exercise group. The exercise group had statistically increased in peak torque of 23.0% for plantarflexion, 14.3% for dorsiflexion, and 44.6% for inversion and 28.4% for eversion. (Figure 4.25)

(iii) Average power

No significant changes were found for average power in all 4 ankle movements for the non-exercise group in the two isokinetic tests. However, for the exercise group, average power had increased significantly; 32.2% for ankle dorsiflexion, 44.3% for plantarflexion and eversion, 55.2% of inversion. (Figure 4.26)

(iv) Peak torque acceleration energy

Insignificant differences were found between the initial and second isokinetic testings of the non-exercise group. The torque acceleration energy of the exercise group had increased significantly, 21.1% for plantarflexion, 27.0%

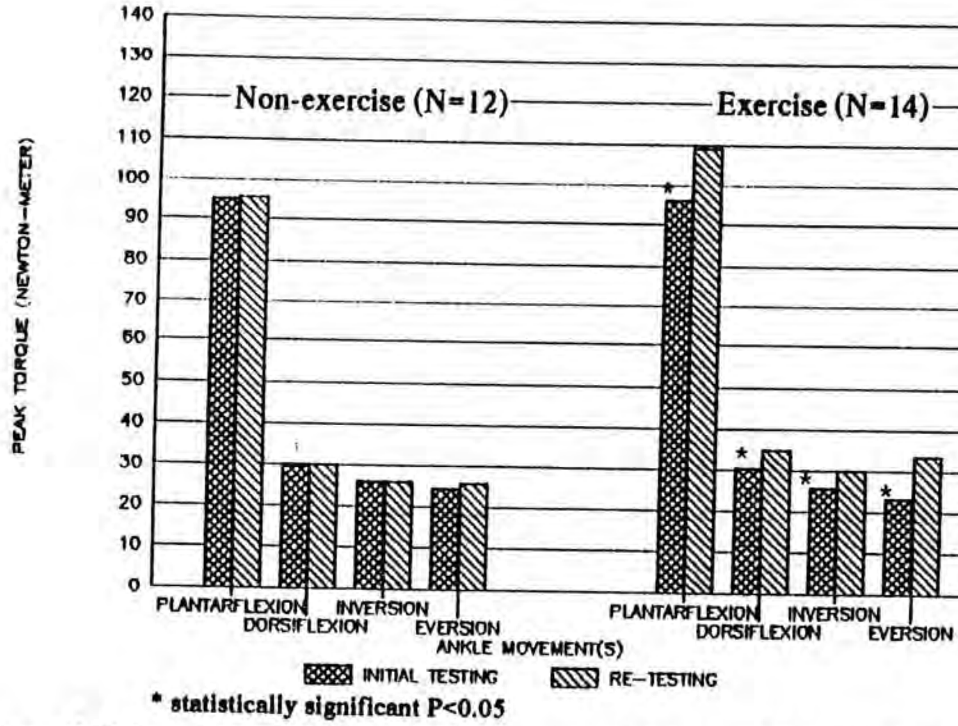


Figure 4.24 Peak Torque at 60°/second - Initial and Re-test for Subjects with Ankle Sprains in Exercise and Non-exercise Groups

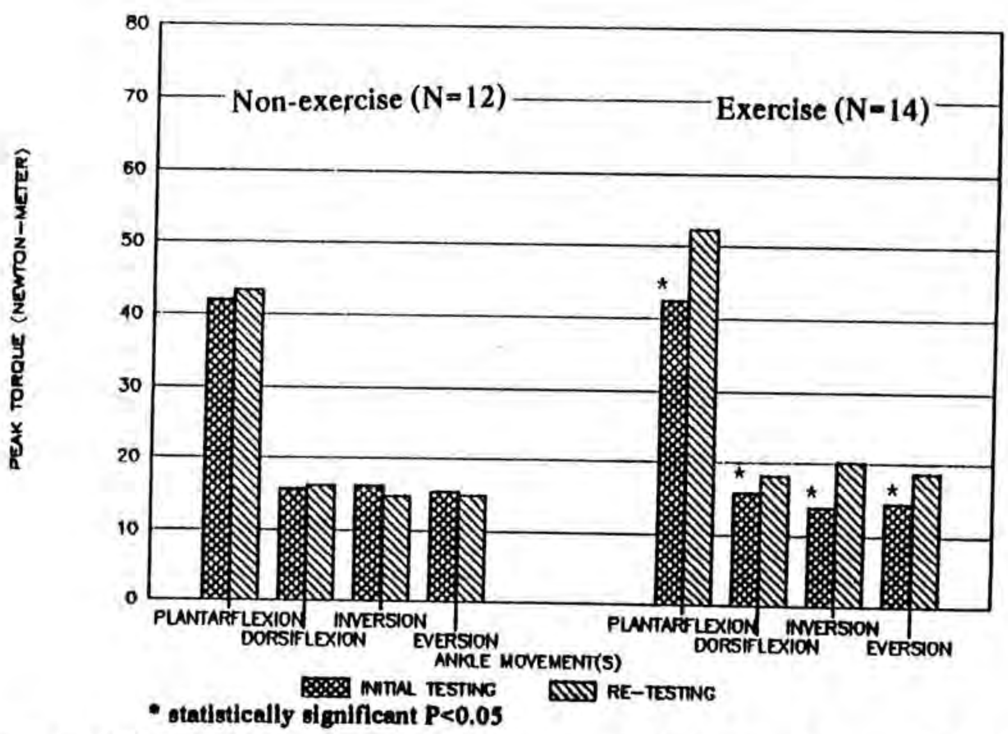


Figure 4.25 Peak Torque at 180°/second - Initial and Re-test for Subjects with Ankle Sprain in Exercise and Non-exercise Groups

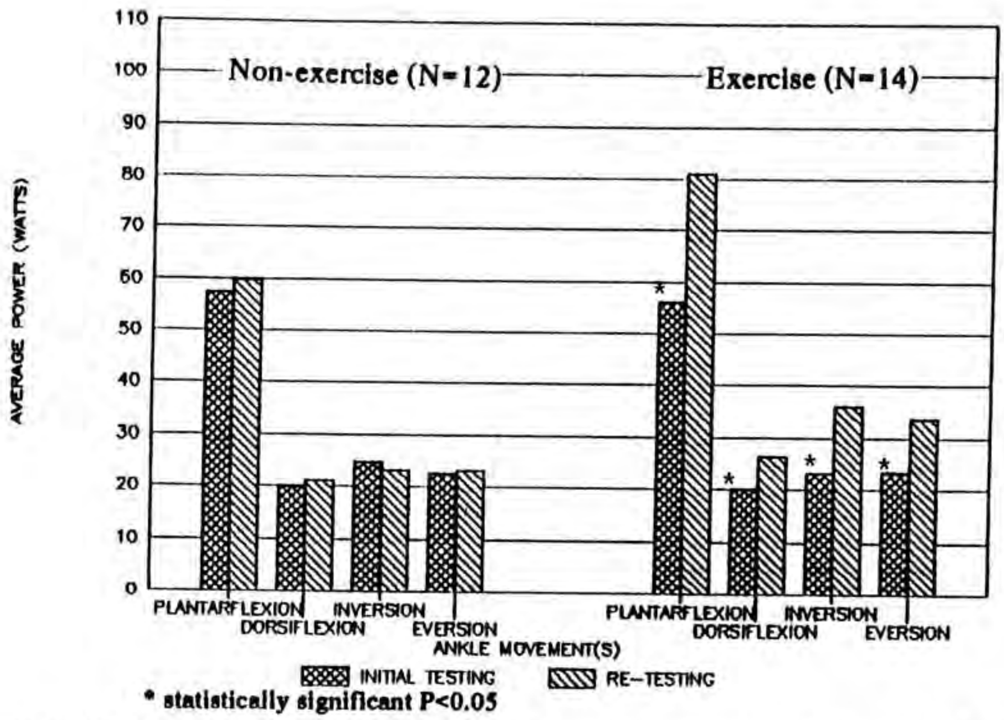


Figure 4.26 Average Power - Initial and Re-test for Subjects with Ankle Sprains in Exercise and Non-exercise Groups

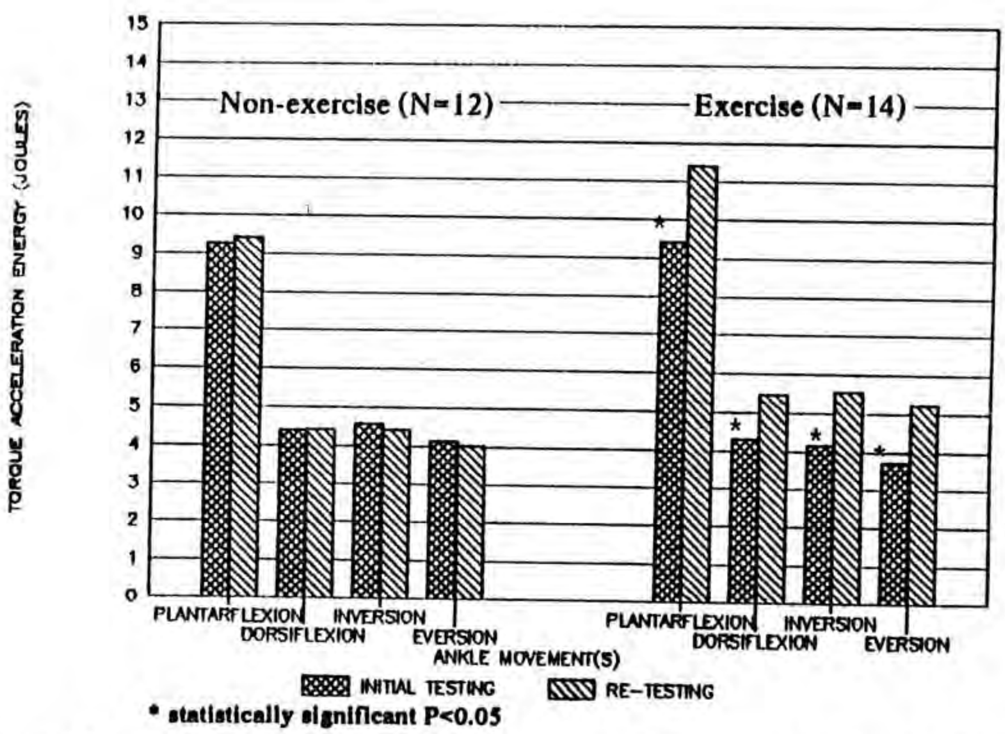


Figure 4.27 Torque Acceleration Energy - Initial and Re-test for Subjects with Ankle Sprains in Exercise and Non-exercise Groups

for dorsiflexion, 33.4% for inversion and 40.2% for eversion. (Figure 4.27)

(v) Total work output

The exercise group had a mean increase in total work output of 34.5% for plantarflexor, 23.5% for dorsiflexor, 55.5% of invertors and 44.4% for evertors in the second isokinetic evaluation, but no significant changes were found in the non-exercise group. (Figure 4.28)

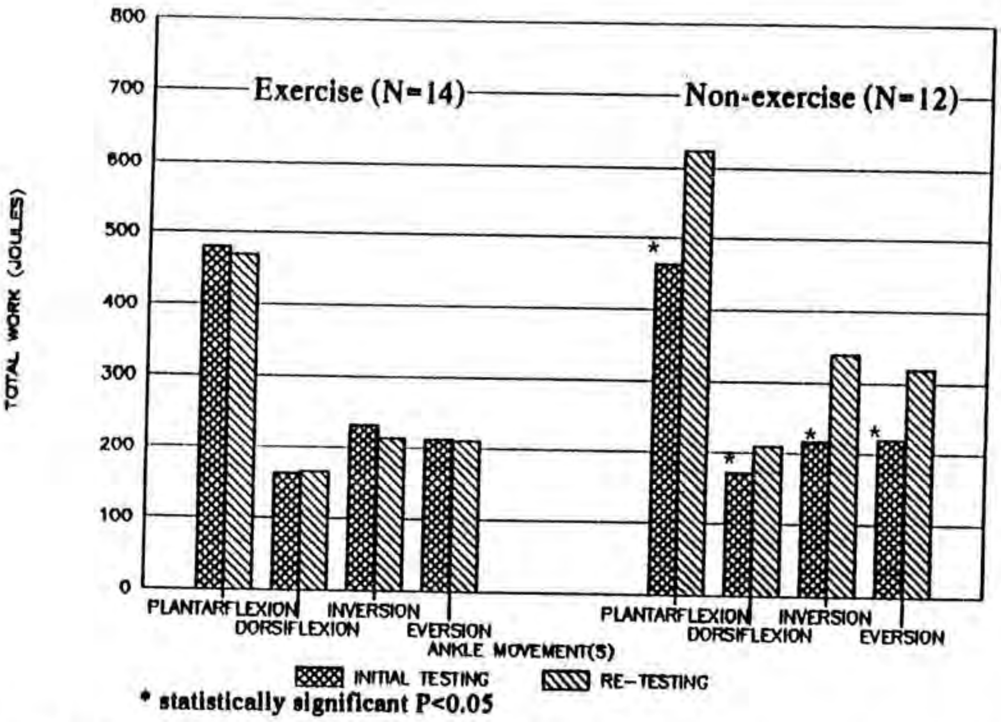


Figure 4.28 Total Work - Initial and Re-test for Subjects with Ankle Sprain in Exercise and Non-exercise Groups

4.3.3 Correlation of Various Isokinetic Parameters of the Ankle with Ankle Functional Rating Scores

In order to identify the relationship between the changes in various isokinetic muscular parameters of the ankle in respect to the changes in ankle functional rating scores of each subject, correlation tests were carried out. Wilcoxon sign-rank test was employed to identify and to establish the relationship between the isokinetic measurements and functional rating measurements.

The changes in isokinetic measurement of various muscular parameters of the ankle from the initial and second isokinetic evaluations were calculated for each subjects. These parameters included relative peak torque at 60°/sec and 180°/sec, torque acceleration energy, average power and total work of ankle dorsiflexor, plantarflexor, invertor and evertor.

The change in isokinetic measurements of muscular parameter was expressed as:

[(P2S1 - P1S1) / P1S1] x 100%

where P1 = datum in the initial test

P2 = second functional rating score

S1 = of subject 1

The change in ankle functional rating score was expressed as:

$$[(F2S1 - F1S1) / F1S1] \times 100\%$$

where F1 = initial functional rating score

F2 = second functional rating score

S1 = of subject 1

The correlational coefficient (r) between the changes in various isokinetic parameters of ankle dorsiflexor, plantarflexor, invertor and evertor, with the changes in functional scores were listed below.

(I) For ankle dorsiflexor:-

	Functional score VS	r
(i)	Peak torque at 60°/sec	0.1595
(ii)	Peak torque at 180°/sec	0.0316
(iii)	Torque acceleration energy	0.2474
(iv)	Average power	0.2579
(v)	Total work	0.1618

(II) For ankle plantarflexor:-

Functional score VS		r
(i)	Peak torque at 60°/sec	0.3429
(ii)	Peak torque at 180°/sec	0.0688
(iii)	Torque acceleration energy	0.5733
(iv)	Average power	0.3136
(v)	Total work	0.1627

(III) For ankle invertor:-

Functional score VS		r
(i)	Peak torque at 60°/sec	0.1058
(ii)	Peak torque at 180°/sec	0.1911
(iii)	Torque acceleration energy	0.2214
(iv)	Average power	0.2634
(v)	Total work	0.0885

(IV) For ankle evertor:-

Functional score VS		r
(i)	Peak torque at 60°/sec	0.1475
(ii)	Peak torque at 180°/sec	0.1911
(iii)	Torque acceleration energy	0.0786
(iv)	Average power	0.0653
(v)	Total work	0.1212

V. DISCUSSION

5.1 Epidemiological Study

The main purposes of this epidemiological study are to identify the prevalence of recurrent ankle sprain among the Hong Kong Chinese athletes, to obtain information on the relationship between the number of occurrence times of ankle sprains and residual symptoms; and on how these residual symptoms affects sports performance.

In this study, a total of 380 athletes with a total of 563 sprained ankles were recorded. Of the 563 injured ankles, 73.5% had recurrent sprains and 22.0% had multiple sprains for 5 times or more. Smith (1986) reported 80% of his basketball players had recurrent sprains. Thus recurrent ankle sprain is common among athletes.

In the analysis of those who had unilateral ankle sprain, it was noted that the dominant leg was more vulnerable to sprain than the non-dominant one. Injury to the dominant ankle was 2.39 times higher than the non-dominant one. Ekstrand et al (1982) reported that ankle sprain was more common in the dominant leg ($P<0.005$) and suggested that this was due to the dominant leg being more exposed to forced inversion in jumping and kicking. Cox (1984) said that when jumping, the foot would naturally fall into plantarflexion and inversion, which was a loose-packed position of the ankle joint; and when landing, muscles of the ankle, namely the dorsiflexor and the evertor, needed to bring the foot to a more neutral position, if the timing in the positioning of ankle during landing was incorrect, ankle sprain might occur.

The Hong Kong national team athletes who participated in sports more frequently and spent more hours per training session than the competitive and recreational athletes ($P<0.05$) were expected to have more ankle sprains than the other two groups. However, this was not the case in this study, the national team athletes did not show a higher incidence of ankle sprains ($P>0.05$). Could it be that having a higher skill level in performance and being better equipped in the national team would reduce the incidence of traumatic ankle injuries ? Could it be that the national athletes have a better knowledge in carrying out a proper warming-up and stretching programme which is often emphasized in the prevention of sports injuries? Further study in assessing the knowledge of warming-up, skill levels in various groups of athletes in relation to the incidence of sports injuries could be carried out.

In this study, only 41% of the injured ankles were reported to be completely symptom free, while 59% complained of one or more residual symptom(s) of either pain, crepitus, instability, weakness etc. in their ankles. Freeman (1965) reported that 40% of injuries to lateral ligaments had functional instability. Smith (1986) reported that half of the players with recurrent sprains had residual problems, and Staples (1972) reported that only 58.7% of sprained ankles completely recovered after 10.4 years of follow-up. Hansen et al (1979) also reported a 20.8% of patients with ankle sprain had residual symptoms with a 3.1-6.1 years of follow-up. Chronic residual symptoms were not uncommon for those who had sustained ankle sprains. Athletes in this study seemed to have a slightly higher percentage in residual symptoms when compared with other studies. This might be due to the fact that athletes in this study were very active in sports and most of them were at competitive or highly competitive level which demand high exertion to their ankle joints. Therefore, residual symptoms might be more pronounced in athletes under high stress activities than in normal patients.

In this study, 30.2% of athletes had pain around their ankle joint and it was the major complaint of athletes with previous ankle sprains. Landeros et al (1968) reported that chronic form of post-traumatic anterior ankle instability would lead to chronic pain at the ankle joint and some might have intermittent ankle swelling. Visser et al (1980) in his examination of chronic ankle sprains, residual problems of chronic swelling, persistent pain, popping, insecurity of ankle and a decrease in the activity level were present in his clients. This study found that athletes who had higher incidents of sprains reported a higher percentage in the residual symptoms of their ankles ($P<0.05$). Residual symptoms of crepitus, weakness, instability and stiffness were significantly higher with the increase in the number of times of recurrent ankle sprains ($P<0.05$). Ankle instability or give-way became the major complaint for athletes with multiple episodes of ankle sprains ($P<0.05$). This study did support other studies that functional instability was the major residual problems, especially for those with multiple ankle sprains. (12, 35,52,73,135)

This study had shown that the frequency in occurrence of various residual symptoms was related to the number of times of ankle sprains; besides, it had also shown that the degree in the level of athletic performance being affected was related to the number of times of ankle sprains ($P<0.05$). Garn et al (1988) mentioned that high incidence of chronic instability could affect participation in sports related activities. This was especially true for athletes at a highly competitive level. This study showed that with the same number of times of ankle sprains, the degree in the level of athletic performance being affected was significantly higher in the Hong Kong national teams than among the competitive athletes and the recreational athletes ($P<0.05$). This might be due to more frequent training at a higher level are required for the national athletes, thus placing more stress on their ankle joints. The training of these athletes is highly demanding. They are required to be both physically and mentally "fit" for the enhancement of their performance. Proper rehabilitation would be beneficial for the injuries, but very often athletes did not seek early medical attention (125), which defer proper rehabilitation, especially in an injury like ankle sprain which happens so often and yet appears to be considered "trivial" among athletes. Further study on the athletes' attitude towards their injuries would be useful in the planning of education programme for the management, prevention and rehabilitation of sports injuries.

In this study, there was a special finding concerning the psychological impact on athletes after ankle sprains. 35 out of 380 athletes (9.2%) had reported that their performances were affected because psychologically they were afraid that strenuous activities would cause pain and other symptoms or recurrent injuries to their ankles. There was a lack of confidence in participating in sports activities. This would be a great disadvantage especially among highly competitive athletes when confidence is a key for winning. Would a sports psychologist be necessary for bringing athletes back to sports after an injury?

5.2 Evaluation for Normal Non-injured Ankle

In measuring muscular strength, it is important to have an objective and a quantitative measurement. Cybex

II+ isokinetic dynamometer is one of the equipment that could be employed in providing both slow and high speed measurements for muscles including strength, power, work and torque acceleration energy. High speed measurement is important as this could simulate functional limb speed and provide information about muscular characteristics at high velocity movements.

Although isokinetic testings could provide objective evaluations for muscular parameters, testing results often depend on motivation of subjects undergoing the testings, the machine settings, the alignment and fixation of subjects, and sufficient practicing trials for the subjects to accommodate to the testing equipment. Therefore, in this study, a clear and full explanation on the testing procedure was given to gain co-operation from all subjects. Subjects were given trails to familiarize themselves with the isokinetic equipment before the testing. The same tester worked through all testings to eliminate inter-tester error and obtain reliable results. In isokinetic rehabilitation, since resistance provided by machine is equal to the applied force, motivation of athletes was important. The underlying basic principle in isokinetic training was also explained in order to gain the co-operation of the training subjects so they would work maximally to have the maximum training effect.

Two testing speeds had been chosen for this isokinetic study on ankle musculatures. One is a low speed (60°/second) and the other is a relatively high speed (180°/second). Peak torques or maximum force that muscles exerted are measured in both slow and high speed testings; torque acceleration energy, total work and power of the muscles were obtained in fast speed testing. For previous isokinetic studies on ankle especially on ankle inversion/eversion, test speeds of 120°/second or lower were employed, and usually only peak torque measurement was obtained. Apparently this is the first study which has this comprehensive array of performance data particularly at high speed and is more relevant to the actual situation in sports.

This isokinetic study consisted of 50 subjects (25 males and 25 females) with no history of ankle injuries. They were tested isokinetically for 4 ankle movements including ankle dorsiflexion, plantarflexion, inversion and eversion. With a view to develop normative data of ankle for the Hong Kong Chinese population. Normative data is useful as a guideline for testing, rehabilitation and training goal (144).

Results showed that mean peak torque of ankle dorsiflexors of the dominant ankles was significantly stronger than that of non-dominant ankles at both 60°/second and 180°/second. There was no significant difference in plantarflexion strength between two legs. Scranton et al (1985) in his study on isokinetic dorsiflexion /plantarflexion reported that no difference was found in peak torques between left and right legs. Sepic et al (1986) also reported that no difference in dorsiflexion/plantarflexion strength was found between two legs when tested isometrically. Studies by Fugl-Meyer et al (1980) and O'berg et al (1987) however reported that left ankle plantarflexor was statistically higher in peak torque than right ankle's. Differences in results among these studies could be due to the inconsistency in defining dominancy of leg, and also the difference in ankle positioning during the testings. These authors used the data on the left side to compare with that of the right side, however the dominancy of the leg might vary individually and thus causing difference in results. Besides, could racial differences be a cause of different muscular performance ?

Peak torques of invertors and evertors showed no significant difference between ankles measured at 60°

/second; but at 180°/second, evertors of dominant ankles had a higher peak value than non-dominant ones ($P<0.05$). Wong et al (1984) reported that no significant difference in peak torque between dominant and non-dominant ankles at 30°, 60° and 120°/second, except evertor of female's left leg was weaker at 30°/second. Leslie et al (1990) also reported that no significant bilateral difference in peak torques of ankle invertors and evertors was measured at 30°/second and 120°/second. The bilateral differences in peak torque measurement at high speed (180°/second) might be due to the evertor of non-dominant ankle was being less effective in generating force at high speed movement. Therefore, in case of injury to the non-dominant ankle, high speed training to restore muscular balance in the non-dominant ankle evertor would be necessary.

This study showed that peak torque of dorsiflexor at 60°/second and 180°/second and evertor at 180°/second were approximately 8% higher in the dominant ankle. Total work and average power of these two groups of muscles were approximately 10% higher in the dominant ankles. Therefore the dominant ankles were higher not only in peak torque, but also in total work output and power.

Torque acceleration energy (TAE) can be quoted as a measurement of the "explosiveness" of muscle contraction. It can also be referred to as the rate of recruitment of muscle fibers. It is important for muscles to function quickly and adequately during unexpected trauma (26,74). Therefore, torque acceleration energy measurement could be used as objective data for dynamic functional assessment of the efficiency of muscle contraction. This study had shown that in non-injured ankles, dorsiflexors and plantarflexors of the dominant ankle had significantly higher torque acceleration energies. However, no significant bilateral difference in torque acceleration energies were found in ankle invertors and evertors . This could be that the dominant leg is usually used more in jumping movement, thus get a faster rate in the recruitment of muscle fibers during fast velocity movements. However, ankle invertors and evertors were mainly served to maintain balance of the ankle, therefore torque acceleration energies of invertor and evertors in both ankles were similar.

In the comparison of isokinetic parameters between male and female subjects, relative peak torques of ankle plantarflexors and dorsiflexors of the female were approximately 80% of that of the male at both 60°/second and 180°/second. Evertor peak torque of female was approximately 76-77% of that of male. Fugl-Meyer et al (1980) in studying plantarflexors strength between male and female, reported that the maximum strength of plantarflexor was 35% lower in female than in male. Since absolute peak torque instead of relative peak torque was used in his study for data comparison, and generally, female were lighter than males, differences in torque measurements between sex would appear to be greater. Wong et al (1984) reported that only the non-dominant ankle evertors of female were weaker than that of the male. However, in this study, the male had a consistently higher relative torque of bilateral ankle evertors than female. Is it because of racial difference ? Further study on racial or cultural influence in muscular characteristics would be a topic of interest.

Results in this isokinetic testing were in agreement with other investigations that dynamic torque decreased with increasing speeds of movement. A drop of 40-50% in ankle dorsiflexion and plantarflexion peak torque, and a drop of around 40% in ankle inversion and eversion peak torque were demonstrated, when compared peak torque at 180°/second with that at 60°/second. This decrease in strength was suggested as the insufficient time for muscle fibers to form cross bridges between the actin and myosin when the speed of muscle contraction increased (145).

Lofvenberg (1991) said that reciprocal muscle group ratio, being the quotient of maximum torque of 2 reciprocal muscle groups, was an indication of joint balance and stability. Its accurate measurement was important for injury prevention and rehabilitation. Results of this study showed ankle dorsiflexor was approximately 1/3 and 2/5 of plantarflexors at 60°/second and 180°/second respectively. Scranton et al (1985) reported that dorsiflexor was approximately 1/3 of plantarflexor at 30°/second and 1/2 of plantarflexors at 180°/second. Davies (1985) reported in his ankle norms that ankle dorsiflexion /plantarflexion ratio at 60°/second was 3.5:1 and at 180°/second was 2:1. In this study, the peak torque ratio of ankle dorsiflexion /plantarflexion at high speed was lower when compared with other studies. One possible explanation was that ankle dorsiflexors in Hong Kong Chinese was less efficient to generate torque especially at high speed than plantarflexors. Further study may be needed to confirmed this point.

In this study, ankle invertors were consistently stronger than the evertors at all test speeds. This coincided with the studies by Wong et al (1984), Leslie et al (1985) and Sepic et al (1986). Mean peak torque ratios of eversion to inversion at slow and fast speeds were close to each other and had similar results as in the studies by Wong and Leslie. These peak torque ratios would be useful in muscle rehabilitation, since peak torque might vary between subjects depending on body size, sex and activities, but the ratios should remain fairly constant, thus could be used as a reference for muscular balance in rehabilitation.

Mean peak torque ratio of ankle dorsiflexion /plantarflexion in the injury group were lower than that of the normal group at both 60°/second and 180°/second for both injured and non-injured ankles (Appendix IV). In the injury group, subjects were mainly athletes at competitive level, these subjects might require stronger ankle plantarflexors for running, jumping activities thus lead to a lower dorsiflexion to plantarflexion ratio. Fugl-Meyer et al (1981) reported plantarflexor strength of athletes was higher than non-athletes while dorsiflexor strength of athletes and non-athletes was similar. Davies et al (1980) in his study with United

States Olympic skiers, ankle dorsiflexion /plantarflexion ratio was also lower in athletes than in normal subjects. Mean peak torque ratio of ankle eversion to inversion was also higher in the injury group than in the normal group for both injured and non-injured ankles. This could be interpreted as ankle evertors being stronger in athletes than in normal subjects. Strong evertors are necessary for positioning of the foot in neutral position during jumping and landing in most sports activities. Therefore, in isokinetic evaluation, bilateral limb comparisons are necessary for assessing the individual's muscle function. Further evaluation for isokinetic parameters of ankle for athletes in individual sports would be of help in identifying muscular characteristics or muscular requirement for athletes in individual sports, thus aiding in the planning, training or rehabilitation programme for athletes in individual sports.

5.3 Evaluation for Ankle with Inversion Sprain

In this session, results of various findings for ankles with recurrent inversion sprains, including anterior draw sign, isokinetic parameters, range of motion of ankle dorsiflexion and ankle functional rating scale will be discussed. In order to have a more comprehensive isokinetic evaluation, muscular parameters of ankles with recurrent sprains would be compared with those of normal subjects. Effects of isokinetic training for injured ankles and results in ankle functional rating scale will also be discussed.

Since no specific method has been developed to establish an exact diagnosis and grading for ankle sprain, it is difficult to confirm whether a partial or complete ligamentous injury had occurred. The choice of subjects in this study relied heavily on the subjects' injury histories. Hence the severity of injuries might vary and cause variations in muscular strength and functional score measurements.

Anterior draw test was employed in this study to assess the stability of ankles after sprains. Reasons for employing this assessment method were: firstly, this was a non-invasive procedure. Secondly, since anterior talo-fibular ligament was the first ligament to be torn in inversion sprain, anterior draw test would be a more sensitive test for directing lateral ligamentous injuries by showing abnormal anterior displacement of the foot on the tibia when the heel was pulling forward (18,72). Thirdly, in clinical practice, cost, time effectiveness, resources and risk to benefit ratio of a method chosen had to be taken into account (39,126), thus anterior draw test was the method of choice for assessing stability of ankle joints after sprains (12,18,42,47,71,72,79).

In this study 12 out of 31 subjects (38.7%) with recurrent ankle inversion sprains had demonstrated positive anterior draw sign with manual assessment. In other studies, subjects with lateral ligament ruptures might not always produce a marked anterior joint displacement even with stress X-ray taken (39,79). However, this method would allow clinicians to make a fast and relative simple assessment on the stability of the ankle after sprain. This aided the clinicians in the planning the most appropriate management method and rehabilitation programme, especially when marked anterior instability of the ankle was detected. This mechanical instability might lead to future functional instability of the ankle (10,12,79).

Comparing active and passive range of ankle dorsiflexion between bilateral ankles, the injured ankle had consistently decreased in the range of motion in active and passive ankle dorsiflexion ($P<0.05$). Since in the normal group , no bilateral difference in dorsiflexion range was measured, these discrepancies in the range of motion indicated that tightness in the calf muscle after inversion ankle sprain did exist. Tight calf muscle was suggested as one of the risk factors for recurrent ankle sprains (18,143). It is because this tightness would limit the range of ankle dorsiflexion and had a bowstring effect in the ankle. The ankle would then have a greater tendency to be in an inverted position, thus leading to a higher incidence in inversion injuries (67,143). The decrease in ankle dorsiflexion range could also be due to pain and immobility after injury. The lack of a proper stretching programme would increase tightness of the calf muscle. This would be one of the predisposing factors for recurrent ankle inversion sprains (18,67,82,125,143).

Unlike Cybex isokinetic testing, ankle function rating scale was a subjective method of assessment. Subjectivity could be a source of error. Firstly, subjects might want to please the tester and give a unreliable answer. Secondly, subjects in the training group might feel that training should have a positive effect on the injured ankle and then give a higher rating score. In order to avoid these errors, clear instructions were given to all subjects and they were asked to provide true information. Moreover, subjects were not told that a self re-assessment with the same functional rating scale questionnaire would be performed, in order to avoid subjects from trying to memorize their score points giving bias to their answers.

Reports from other studies had shown that muscular weaknesses, especially ankle evertors and dorsiflexors, were present in those with ankle inversion sprains (6, 46,75,82,85,109,114,135). In order to improve the objectivity of measurements, Cybex II+ isokinetic dynamometer was employed in the evaluation of ankle muscular parameters for subjects with inversion ankle sprains.

In this study, bilateral discrepancies in muscular parameters between dominant and non-dominant non-injured ankles were present in normal subjects. These were considered as "normal" differences and were used as references in analyzing muscular data in the injury group. In this study, when comparing various muscular parameters of the ankles, the differences between injured and non-injured ankles with "normal" muscular differences between bilateral ankles were defined as "relative" differences.

In this isokinetic testing for ankle with recurrent sprains, results showed that for subjects with the dominant ankle injured, muscular parameters including peak torques, total work, average power and torque acceleration energy were generally decreased in the injured dominant ankle relative to non-injured side. Muscular parameters of ankle dorsiflexors and evertors were significantly lower in the injured ankle relative to the non-injured side. For subjects with non-dominant ankle injury, mainly the muscular parameters of ankle evertor in the non-dominant injured ankle were significantly lower relative to the dominant one. The decreases in peak torques, average power, total work of musculature of the injured ankle could indicate that there was not only a decrease in muscle strength, but also a decrease in muscle endurance in the injured ankle. Furthermore, the decrease in torque acceleration energy of the injured ankle could indicate that the reaction time of the muscle in the injured ankle had increased, thus the muscle was less effective and less efficient to general force to react and counteract a sudden stress. Tropp (1986) reported that evertors weakness were detected for subjects with ankle sprains tested isokinetically at test speeds of 30°/second and 120°/second. But there were no comparison between the dominant and non-dominant ankles and only peak torques were measured. This study had provided a more comprehensive evaluation on various muscular parameters in the injured ankles.

There was one finding in this study which had not been reported: for subjects with dominant ankle sprains, a more generalized muscle weakening was detected than in those with non-dominant ankle injury. One possible explanation was that the dominant leg was usually the leading leg, and activated more in explosive and strenuous activities, such as jumping, hopping and kicking. Injury to the dominant ankle would require a longer rest period before the subject could return to vigorous and stressful activities which had a high demand on their dominant ankle than for subjects with their non-dominant ankle injured. A shorter period of rest would result in a lesser degree of disuse muscle atrophy and subsequent muscle weaknesses. Therefore, subjects with their dominant ankle injured had a more generalized muscle weakening than those with their non-dominant ankle injured.

Weaknesses of ankle evertors and dorsiflexors were often described as the underlying cause for recurrent ankle inversion sprains. These muscles were important as they served as dynamic support to the lateral ligaments for maintaining the stability of the ankle joint and for counteracting the inversion force in an ankle sprain (26,40,74,128,135). Weaknesses of these muscles were resulted from pain and immobility after the injury, leading to secondary disuse muscle atrophy, thus putting the ankle joint at risk of recurrent injury (47,128). Thus strengthening exercise for the injured ankle was essential to break this vicious cycle of " pain - disuse muscle atrophy - recurrent sprain - pain" .

5.4 Isokinetic Rehabilitation

Since muscular weakness was detected for subjects with recurrent ankle sprains, isokinetic rehabilitation for strengthening of the injured ankle was designed. Velocity spectrum training was employed in this rehabilitation programme. This training protocol was employed because slow speed isokinetic could improve strength at slow speed, while high speed isokinetic could improve strength, power, total work and torque acceleration energy. Most important of all, it could improve functional performance. Motor performance required quick acceleration work, thus high speed isokinetic could train fast twitch fibers, which helped in improving the reaction time in muscle contraction (1,20,49,103,118,124,132). Velocity spectrum training could also promote an optimal neuromuscular response in trained muscles and nervous system (116,131,132,142). It had also been reported that there was a carry-over effect of at least ± 60°/second in isokinetic training. This could serve to reinforce strength gain at each training velocity (23,62,87,131,132).

In this study, subjects in the exercise group showed significant improvement at the retest in all muscular parameters of the trained ankles, including peak torques, torque acceleration energy, total work output and average power. Furthermore, their ankle functional rating score was also significantly increased. For subjects in the control group with no exercise prescription, These changes were not observed. There was no significant change in any of the muscular parameters of the ankles in the retest. There was also no significant change in ankle functional rating score. This could imply that isokinetic strengthening exercise with velocity spectrum training protocol for ankle musculatures was effective not only in improving muscular strength, power, total work and torque acceleration energy, but also in enhancing ankle functional performance. This study supported other studies that resistance strength training could enhance motor performance and functional performance of the trained subjects (20,124,131,132). Therefore, velocity spectrum isokinetic training, with a mixture of speeds for exercising, was recommended for the rehabilitation of ankle injury.

The improvement in motor performance following isokinetic exercise could be related to the isokinetic training effects which have already been discussed. Besides, in resistance training, a change in reflex potential could also be resulted. This could result in an improvement in muscles ability to recruit motor units and discharge them at a faster rate, thus reflex responses in the muscles could be enhanced (116). Training could also shorten the time lag for muscles to act on the joint, and this could induce less stress to the ligamentous structure (58).

However, in the correlation test, a low correlation between the change in isokinetic measurements and the change in functional rating measurements was found. Is the improvement in functional performance not related to the improvement of muscular performance? Or would it be the difference in the scale of measurements in isokinetic and functional evaluations that give rise to a low correlation coefficient when tested statistically?

Isokinetic evaluation was an objective and a parametric measurement, while functional rating scale was a subjective and non-parametric measurement. The difference in the scaling systems in these two methods of assessment of ankle function might result in low correlation when one tried to obtain a relationship between these two methods. Secondly, isokinetic measurement was a very fine and sensitive scale for data measurement, small changes in muscular parameters could be detected when measured isokinetically. Whereas the ankle functional rating scale employed in this study involved the rank ordering values, the changes would not be as fine as in the isokinetic measurement. Besides, in this scaling method, there was a upper limit of 100 points. For instance, even if the ankle's function was excellent, the maximum points the subject could obtain was 100, thus the percentage of improvement would be limited by the upper limit of the scaling itself. Therefore, when one tried to establish a relationship between these two assessment methods of the ankle, the correlation would seem to be low because of the difference in the measuring scales used.

This study also was found that only 2 out of the 16 trained subjects claimed 100% recovery from their ankle injury after the training programme, that was, scoring 100 points in the rating scale. Six weeks isokinetic training might not be sufficient for most subjects in gaining maximal benefit from the exercise. Further study on the optimal training period for ankle sprain rehabilitation is suggested.

A long-term follow-up for the subjects in this injury group could be useful in assessing whether muscle training could significantly reduce the recurrent rate in ankle sprain, by comparing the recurrent rate in the exercise group with that of the non-exercise group. In future study, it is suggested that an objective functional assessment method could be designed and implemented for a boarder view in the evaluation of the effect of isokinetic training on the subjective and objective ankle performance.

Positive changes which included the improvement in various muscular parameters of the ankle and the increase in subjective functional rating scores were obtained as a result of isokinetic training. Muscular training has shown its role in improving ankle muscular parameters and enhancing ankle functional performance. However, other studies have also suggested that factors like calf muscle tightness (which was also noted in this study) and proprioception deficit as predisposing factors for recurrent sprains. Future studies to investigate on other risk factors, such as proprioceptive deficit, calf tightness, which might lead to recurrent ankle sprains, would be of great help to the therapist in the planning of a comprehensive rehabilitation programme. This would be valuable in restoring maximum ankle function and in the prevention of recurrent ankle injury.

5.5 Limitations and Future Direction of Research

There were some limitations in this study. Firstly, there was no easy and accurate method in the diagnosis of the degrees of severity in ankle sprain. Subjects chosen in this study relied heavily on their reports of the clinical picture of their ankles after sprains. The differences in second or third degree sprain might not be easily differentiated. The differences in the severity of sprains might result in a different degree of ankle weakening thus causing variation in isokinetic and functional measurements. The prognosis in returning athletes to full sports activities might also vary. Further research could be directed towards choosing a larger population size and a group of more specific population. For example, subjects could be chosen from the same sports event, with the same number of times of ankle sprain and had stress x-ray taken. These could decrease variation within the population and increase the reliability of the study. The degree of joint laxity in relation to muscular performance could also be a topic for future research.

In order to correlate functional performance with isokinetic results, a quantitative assessment of ankle activities could be designed. For example, the time required to complete a figure-of-eight running could be incorporate into the quatitative measurement. The effect of isokinetic training in improving ankle stability could also be measured with the use of force-plate to assess the stabilometric values of the ankle.

This isokinetic study is only a start of a series of studies on ankle sprain. This study provides a deeper understanding of the role of muscular rehabilitation for ankle injuries. It is hoped that further research on related topic could be carried out. This would help in further deepening our understanding of an ankle sprain. It could also aid the therapists in designing a better rehabilitation programme for ankle sprain management.

VI. CONCLUSION

Ankle joint is one of the most vulnerable joints in athletes, and the most common traumatic injury in ankle is sprain. One of the aims of this study is to identify the prevalence of recurrent ankle sprains, and its related residual symptoms with its subsequent effects in athletic performance. An epidemiological survey was conducted to investigate these points. The results showed that the recurrent rate for ankle sprains in this study was as high as 73.5% . Residual symptom(s) existed in 59% of athletes with sprains. Ankle instability, which existed in 37.9% of athletes, was the major symptoms especially for those with recurrent sprains for 5 or more times. With this high recurrent rate and high occurrence rate in various sprain related residual symptoms, ankle sprain was never an injury that one should take it lightly. Moreover, the level of athletic performance was also affected, especially for those who were highly competitive and had sustained multiple ankle sprains.

A comprehensive evaluation on muscular parameters of ankle was tested isokinetically with Cybex

II+ isokinetic dynamometer in order to obtain normative data for the ankle. Isokinetic results showed that bilateral variations in muscular parameters of ankle were present. Thus these "normal" differences would be used as references in comparing muscular data of subjects with unilateral ankle sprain.

Another aim in this study was to identify if muscular weaknesses were present in subjects with recurrent ankle sprains. Therefore, various muscular parameters of ankles with unilateral recurrent sprains were evaluated isokinetically to obtain objective findings for muscular assessment, with comparison to normative data obtained. Results indicated that evertor muscle weakness was present in subjects with inversion ankle sprain. All muscular parameters of ankle evertor of the injured ankle, including peak torque, average power, total work and torque acceleration energy had decreased significantly. Moreover, a more generalized weakening was found if the dominant ankle rather than the non-dominant ankle was injured. The possible explanation was that subsequent secondary muscle disuse atrophy was more profound in the dominant ankle if it was injured, as it required a longer "rest" period before it could return to its original level of activities. The dominant ankle was at a higher and more demanding level than the non-dominant ankle.

Since muscular weaknesses were detected in subjects with recurrent ankle sprains, isokinetic exercise with velocity spectrum training protocol was designed for strengthening the injured ankles. This isokinetic exercise protocol consisted of fast and slow speeds exercise training for improving both strength and muscle endurance of the ankle. Significant increased in various muscular parameters, including peak torque, average power, total work and torque acceleration energy, of the ankle were found in the training subjects. Thus it was a very effective exercise programme for the ankle. This significant improvement in various muscular data could be due to the effectiveness of this mode of exercise which loaded the muscles maximally throughout the entire range of movement. Furthermore, with velocity spectrum training, both fast and slow twitch fibers could be trained accordingly, thus enhancing both motor and neurological performance. Training effect in velocity spectrum could also be reinforced between speeds by overflowing effect.

Apart from muscular evaluation for ankles with recurrent sprain, the functional performance of the injured ankle was also assessed with the ankle functional rating scale. This was a scoring sheet with questions concerning various symptoms in relation to athletes performance levels. Athletes would self-evaluate their ankle functional ability in both the initial test and retest. Points were given to the answers. Results showed that athletes in the training group had increased significantly in ankle functional rating scores. This indicated that the functional ability of the injured ankles could be improved with the use of isokinetic training.

In conclusion, isokinetic training with velocity spectrum protocol was not only useful in improving various muscular parameters of ankles with recurrent sprains, but also useful in enhancing the functional abilities of the injured ankle .

The difficulty in accurate diagnosis of the degree of ligamentous injury in ankle sprains, the subjectivity in ankle functional rating scale were some limitations and problems encountered in this study. Despite these limitations and problems, this study revealed that ankle sprain is never a "trivial" injury. Residual problems following sprains is not uncommon and recurrent rate is high. Weaknesses were detected, especially in the ankle evertor of the injured ankle. This muscle weakening may be a predisposing factor for recurrent ankle sprains. Isokinetic training for the injured ankle aided in improving its muscle strength and function, which could be explained by ankle musculatures serving as dynamic support to the ankle joint and improving its stability, thus assisting in joint function.

Further research to identify other factors, such as calf muscle tightness or proprioception defect, which might affect ankle function following a sprain would be of great help in the revealing and planning of a comprehensive rehabilitation programme for injury management. A good rehabilitation is also important for the prevention of recurrent injury. Future study could also be directed in the design of an objective functional evaluation method for ankle sprain. The method may include the assessment of various techniques such as running, jumping or turning abilities, following an isokinetic training programme. The effectiveness of isokinetic training upon ankle function could then be evaluated both subjectively and objectively. The finding may lead to a better understanding in the application of isokinetics for rehabilitation of ankle sprain.

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APPENDIX I

足 踝 扭 傷 的 研 究 問 卷

ANKLE SPRAIN STUDY

以 下 是 一 項 由 中 文 大 學 醫 學 院 矯 形 外 科 及 創 傷 學 系 研 究 生 楊 明 珊 對 足 踝 扭 傷 的 研 究 問 卷, 所 有 資 料 均 會 絕 對 保 密. 多 謝 合 作 !

This is a pilot study on ankle sprain among athletes, it is conducted by Josephine Yeung graduate student of the Department of Orthopaedics and Traumatology, Chinese University of Hong Kong. All information will be treated confidentially.

THANK YOU FOR YOUR COOPERATION !

1. 密 碼
CODE ____________________

2. 日 期
DATE ________________________

(I) PERSONAL DATA 個 人 資 料

3. 性 別
SEX : 男 MALE ☐ 女 FEMALE ☐

4. 出 生 日 期
DATE OF BIRTH : ____________________

5. 年 齡
AGE : ________________

6. 主 力 腳
DOMINANT LEG : 左 腳 LEFT ☐ 右 腳 RIGHT ☐

7. 除 了 踝 關 節 扭 傷 外, 下 肢 還 有 沒 有 其 他 較 嚴 重 的 損 傷 或 其 他 影 響 下 肢 的 傷 病
ANY MAJOR INJURY TO LOWER LIMB(S) OR DISEASES AFFECTING THE LOWER LIMB(S) BESIDES ANKLE SPRAIN.

有 YES ☐ 沒 有 NO ☐

如 有, 請 注 明
IF YES, PLEASE SPECIFY ____

____

(II) SPORT ACTIVITY 運動項目

8. 閣下每週參與運動多少次
HOW MANY TIMES DO YOU INVOLVE IN SPORT ACTIVITIES EACH WEEK ?

< 1 ☐ 1 ☐ 2-3 ☐ 4 ☐ > 5 ☐

9. 每次運動平均所耗多少時間
AVERAGE DURATION EACH SESSION ?

< 1 hr ☐ 1 - 2 hr ☐ 2 - 3 hr ☐ > 3 hr ☐

10. 參與最多的兩項運動
THE TWO SPORTS YOU PARTICIPATE MOST OFTEN ARE :

a. ____________________ b. ____________________

11. 運動員類別
TYPE OF ATHLETE :

香港代表隊
HK NATIONAL TEAM : ☐

運動隊/屬會
SPORT CLUB / TEAM : ☐

娛樂
RECREATION : ☐

其他
OTHERS : ☐

如是其他，請注明
IF OTHERS, PLEASE SPECIFY ____________________

____

____

(III) ANKLE PROBLEM(S) 足踝問題

12. 足踝扭傷的次數 (請注明次數)
TIME(S) OF ANKLE SPRAIN

		左 LEFT	右 RIGHT
a)	0	☐	☐
b)	1	☐	☐
c)	2 - 4	☐	☐
d)	> 5	☐	☐

13. 足踝扭傷的原因 (請注明扭傷次數)
MECHANISM OF ANKLE SPRAIN
(PLEASE INDICATE THE NO. OF INJURY OR INJURIES)

		左 LEFT	右 RIGHT
a)	足向外翻 INVERSION SPRAIN	☐	☐
b)	足向內翻 EVERSION SPRAIN	☐	☐
c)	從未發生 NONE	☐	☐

d) 其他 (請注明)
OTHERS (PLEASE SPECIFY) ____________________

14. 最近的一次足踝扭傷是在多少年或月前發生
IN TERMS OF NUMBER OF YEARS OR MONTHS, WHEN WAS YOUR MOST RECENT INCIDENCE OF ANKLE SPRAIN ?

左 LEFT __________ 年 YEARS __________ 月 MONTHS

右 RIGHT __________ 年 YEARS __________ 月 MONTHS

15. 最常足踝扭傷的時間
USUAL OCCURRENCE OF ANKLE SPRAIN(S)

		左 LEFT	右 RIGHT
a)	在運動前 1/3 段時間發生 BEGINNING 1/3 OF GAME / TRAINING	☐	☐
b)	在運動中 1/3 段時間發生 MID 1/3 OF GAME / TRAINING	☐	☐
c)	在運動末 1/3 段時間發生 LATER 1/3 OF GAME / TRAINING	☐	☐

16. 最常引致足踝扭傷的情況
USUAL CAUSE OF ANKLE SPRAIN(S)

	左 LEFT	右 RIGHT
a) 落地不正確 INCORRECT LANDING	☐	☐
b) 失去平衡 LOSS BALANCE	☐	☐
c) 場地不平坦 UNEVEN SURFACE	☐	☐
d) 直接撞擊 DIRECT IMPACT	☐	☐
e) 其他 OTHERS	☐	☐

17. 請問現在有沒有下列關於足踝所引起的困擾
DO YOU HAVE ANY OF THE FOLLOWING PROBLEM(S) WITH THE ANKLE PRESENTLY ?

有 YES ☐ 沒有 NO ☐

如有，請注明
IF YES, PLEASE SPECIFY

	左 LEFT	右 RIGHT
a) 響 CREPITUS	☐	☐
b) 腫脹 SWELLING	☐	☐
c) 乏力 WEAKNESS	☐	☐
d) 痛 PAIN	☐	☐
e) 不穩定 INSTABILITY	☐	☐
f) 硬 / 緊 STIFFNESS	☐	☐

g) 其他（請注明）
OTHERS (PLEASE SPECIFY) ------------------------------

18. 你 如 何 評 估 你 現 在 足 踝 傷 患 的 情 況
HOW DO YOU GRADE YOUR PRESENT ANKLE PROBLEM(S) ?

	左 LEFT	右 RIGHT
a) 沒 有 NIL	☐	☐
b) 輕 微 MILD	☐	☐
c) 普 通 MODERATE	☐	☐
d) 嚴 重 SEVERE	☐	☐

19. 足 踝 傷 患 對 你 現 在 的 運 動 表 現 有 沒 有 影 響
DOES YOUR ANKLE AFFECT YOUR PRESENT SPORT PERFORMANCE ?

	左 LEFT	右 RIGHT
a) 從 來 沒 有 NEVER	☐	☐
b) 有 時 SOMETIMES / OCCASSIONALLY	☐	☐
c) 經 常 OFTEN	☐	☐
d) 總 是 VERY OFTEN	☐	☐

如 有, 請 注 明 足 踝 傷 患 如 何 影 響 你 的 表 現
IF YES, PLEASE SPECIFY HOW IT AFFECTS YOUR PERFORMANCE :

____

____

問 卷 到 此 結 束, 多 謝 !
THIS IS THE END OF THE QUESTIONNAIRE .
THANK YOU VERY MUCH !

APPENDIX II

INFORMED CONSENT FOR A CYBEX MUSCLE TEST

INTRODUCTION

Ankle sprain is a very common traumatic injury especially among the sports population. Once a person had sustained a sprained ankle, recurrent ankle sprain is often occurred. Muscular weakness around the ankle is often considered as one of the factors lead to recurrent ankle sprain.

The objective of this research is to evaluate the muscular characteristics around the ankle of normal people who have never sustained any injury to their ankles and feet. This helps to obtain a norm for the later comparison with those who have recurrent ankle sprains, to find out if there is any relationship between muscular weakness and deficiency in muscle endurance or power, and recurrent ankle sprain.

Your effort and contribution is extremely valuable in the future direction of planning and rehabilitation of ankle injuries.

EXPLANATION OF THE CYBEX TEST

You are required to come to the the Human Performance Laboratory of the Jubilee Sports Centre for twice. In each visit you need to perform muscle test on either ankle DF/PF or ankle INV/EV in 2 speeds (fast and slow) . In each movement, you need to do 5 repetitions at slow speed to test your muscle strength and do 25-50 repetitions at fast speed to test your muscle endurance and power. In each repetition, you must exert your effort. In order not to fatique the muscles of the ankles , the muscle groups will be tested in 2 sessions of visit.

RISKS AND DISCOMFORT

There exists the possibility of certain changes occuring during the test. They include muscle pain, muscle cramp and disorder of breathing, and in rare instance fainting. Every effort will be made to minimize these through the preliminary examination and by observations during testing. Trained personnel and required equipments are available to deal with unusual situations which may arise.

INQUIRIES

Any questions about the procedures used in the test are encouraged. If you have any doubts or questions, please ask us for further explanations.

INFORMED CONSENT FOR A CYBEX MUSCLE TEST

FREEDOM OF CONSENT

Permission to perform this muscle test is voluntary. Information obtained will be treated as confidential, however, it will be used for statistical or scientific purposes with your right of privacy retained.

I have read this form and I understand the test procedures that I will perform. I consent to participate in this test.

____

Signature

____________________ ____________________

Date Witness

Questions : ____

____

CONFIRMATION

Do you have any major trauma, injury or have done any surgery on your major joints or muscle groups of the lower limbs within three years' time, and no previous injury of ankles and feet ? Yes/No

If YES, which joints have problems : ______________________________

and what are the problems : __________________________________

ANKLE FUNCTION RATING SCALE
足踝活動評估計算表

NAME 姓名 ______________ SEX 性別 _____ DATE OF BIRTH 出生年月 ___________ DATE 日期 ____

INJURED ANKLE 受傷足踝 ☐ left 左 ☐ right 右

1. PAIN 疼痛 (20)

☐ 20 No pain
沒有疼痛

☐ 16 Pain after strenuous activity
在劇烈活動後有疼痛

☐ 13 Pain during strenuous activity
在劇烈活動時有疼痛

☐ 10 Pain after moderate activity
在中等程度活動後有疼痛

☐ 7 Pain during moderate activity
在中等程度活動時有疼痛

☐ 4 Pain with light activity
輕微活動已經有疼痛

☐ 0 Pain at rest
不活動亦感疼痛

INTENSITY OF PAIN 疼痛程度

☐ + 2 Mild 輕微

☐ + 1 Moderate 中等

☐ + 0 Severe 嚴重

2. SWELLING 腫 脹 (10)

☐ 10 No swelling. 沒有腫脹.

☐ 8 Slight, asymptomatic.
輕微，但沒有疼痛感.

☐ 6 Occasional swells after strenuous activity.
劇烈活動後間中有腫脹.

☐ 4 Occasional swells after moderate activity.
中等程度活動後間中有腫脹.

☐ 2 Swells after light activity.
輕微活動後會有腫脹.

☐ 0 Swells all the time and symptomatic.
經常腫脹及有疼痛感.

3. STABILITY 穩 定 性 (20)

☐ 20 Never turns or twist.
後未感覺過足踝容易扭動或不穩.

☐ 16 Turns infrequently, can participate in vigorous sports, but with cautions.
偶爾感覺足踝有扭動或不穩，能參與劇烈活動，但會加倍小心.

☐ 12 Turns infrequently, can participate in vigorous sports, but require protection devices or tapping.
偶爾感覺足踝有扭動或不穩，能參與劇烈活動，但需用護踝或綳帶保護.

☐ 8 Turns frequently with moderate activity, require guarding, not able to cut or twist.
中等強度的活動經常會翻扭足踝，需要保護，不能做快速地交叉移動或變向動作.

☐ 4 Turns frequently during light activity (once every month).
輕度活動時也經常感覺足踝容易翻扭或不穩 (一月一次).

☐ 0 Turns frequently even during walking, requires constant guarding.
平常走路也會足踝翻扭，必須長期用護踝或保護.

4. STIFFNESS 硬 / 緊 的 感 覺 (10)

☐ 10 Never stiff.
從未有過硬/緊的感覺.

☐ 8 Stiff before warming up, loosen up after warming up, not affecting strenuous activity.
熱身前感覺硬/緊, 在熱身後便正常, 不防礙劇烈活動.

☐ 6 Stiff even after warming up, some limitation to strenuous activity.
熱身後仍覺硬/緊, 對劇烈活動有些少防礙.

☐ 4 Stiff, limited to moderate activity.
硬/緊, 只能參與中等程度的活動.

☐ 2 Stiff, limited to recreational activity.
硬/緊, 只能參與一般娛樂性的運動.

☐ 0 Stiff all the time, affecting normal activity.
經常硬/緊, 影嚮日常活動.

5. OVERALL ACTIVITY FUNCTION 總 体 活 動 功 能 (20)

☐ 20 No limitation, normal ankle, able to participate in strenuous sports or activity at competitive level fully.
正常足踝, 能參與任何劇烈或比賽性質的運動, 而不覺有影嚮.

☐ 16 Performs sports including vigorous activities at competitive level fully, but with some guarding or limits.
能參與劇烈或比賽性質的運動, 對運動表現有輕微影嚮, 需小心或保護足踝.

☐ 12 Performs moderate sports, more strenuous sports involving twisting or cutting cause problems.
能參與中等強度的運動, 但劇烈活動需要急轉等會有問題發生.

☐ 8 Light or recreational activities only, more vigorous activities cause problems.
只能參與輕微或娛樂活動, 加大運動量便會產生間題.

☐ 4 Limited to activities of daily living, walking and quit sports.
只能作日常生活活動，不能參與任何運動.

☐ 0 Disabling, affecting daily activities or work.
常有困擾，影嚮日常工作.

6. RUNNING 跑步 (10)

☐ 10 Normal, unlimited.
正常，完全沒有影嚮.

☐ 8 Slight / mild problem.
輕微影嚮.

☐ 6 Moderate problem: run half-speed
有中等程度影嚮:只能以減半的速度跑步.

☐ 4 Moderate severe problem: only 2-4 kilometers
比較嚴重：只能跑不超過 2-4 公里.

☐ 2 Severe problem: can only do light jogging.
嚴重：只能作緩跑.

☐ 0 Very severe problem: only few steps.
非常嚴重：只能跑數步.

7. JUMPING , TWISTING 跳躍，轉動 (10)

☐ 10 Normal, unlimited, full competence, strenuous.
正常，能參與劇烈活動.

☐ 8 Mild / slight: some guarding, but sports possible.
輕微：要小心或保護，但能參與運動.

☐ 6 Moderate problem: gave up strenuous sports, recreational sports possible.
有中等程度的問題：放棄參與劇烈運動，但仍能參與一般娛樂性活動.

☐ 4 Moderate severe problem: affects all sports, must constantly guard, require to change sports that require less jumping or twisting.
問題比較嚴重: 影嚮所有運動，只能改為參與一些不需要跳躍或轉動的活動.

☐ 2 Severe problem: only light activities (swimming)
問題嚴重: 只能參與一些輕微的活動 (游泳).

☐ 0 Very severe problem: cannot participate in any sports.
非常嚴重: 不能參與任何運動.

OFFICIAL USE ONLY

1. CODE:_________

2. SCORE:________

APPENDIX IV

Peak Torque Ratio	Speed Test /sec	Normal Subjects (N=100 Ankles) (%)	Injury Group		
			Non-injured Ankles (N=31)	Injured Leg before Training (N=31 Ankles)	Injured Leg after Training (N=14 Ankles)
DF/PF (x100%)	60 180	33.7 41.5	30.5 38.1	31.7 37.5	31.8 34.8
EV/INV (x100%)	60 180	84.2 79.7	94.3 93.4	91.7 99.4	112.2 92.4

Mean relative peak torque ratio of ankle dorsiflexion/plantarflexion (DF/PF), eversion/inversion (Ev/Inv) of the normal and injured ankles.